

LOAN DOCUMENT

		PHOTOGRAPH THIS SHEET	<div style="border: 1px solid black; width: 50px; height: 50px; margin: 0 auto; border-radius: 50%;"></div>												
DTIC ACCESSION NUMBER	LEVEL	INVENTORY													
	<p style="font-size: 1.2em; margin: 0;">Work Plan for a Treatability Study...</p> <p style="margin: 0;">DOCUMENT IDENTIFICATION</p> <p style="margin: 0;">May 96</p>														
	<div style="border: 1px solid black; padding: 10px; margin: 0 auto; width: 80%;"> <p>DISTRIBUTION STATEMENT A</p> <p>Approved for Public Release</p> <p>Distribution Unlimited</p> </div>														
		DISTRIBUTION STATEMENT													
<div style="border: 1px solid black; padding: 5px;"> <p>ACCESSION FOR</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">NTIS</td> <td style="width: 50%;">GRAM</td> <td style="width: 50%; text-align: center;"><input checked="" type="checkbox"/></td> </tr> <tr> <td>DTIC</td> <td>TRAC</td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td>UNANNOUNCED</td> <td></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td colspan="3">JUSTIFICATION</td> </tr> </table> </div>		NTIS	GRAM	<input checked="" type="checkbox"/>	DTIC	TRAC	<input type="checkbox"/>	UNANNOUNCED		<input type="checkbox"/>	JUSTIFICATION			<div style="border: 1px solid black; height: 150px; margin-bottom: 10px;"></div> <p style="text-align: center; margin-bottom: 10px;">DATE ACCESSIONED</p> <div style="border: 1px solid black; height: 100px; margin-bottom: 10px;"></div> <p style="text-align: center; margin-bottom: 10px;">DATE RETURNED</p> <div style="border: 1px solid black; height: 100px;"></div> <p style="text-align: center;">REGISTERED OR CERTIFIED NUMBER</p>	
NTIS	GRAM	<input checked="" type="checkbox"/>													
DTIC	TRAC	<input type="checkbox"/>													
UNANNOUNCED		<input type="checkbox"/>													
JUSTIFICATION															
<div style="border: 1px solid black; padding: 5px;"> <p>BY</p> <p>DISTRIBUTION/</p> <p>AVAILABILITY CODES</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">DISTRIBUTION</td> <td style="width: 50%;">AVAILABILITY AND/OR SPECIAL</td> </tr> <tr> <td style="height: 40px; vertical-align: bottom; font-size: 1.5em;">A-1</td> <td></td> </tr> </table> </div>		DISTRIBUTION	AVAILABILITY AND/OR SPECIAL	A-1											
DISTRIBUTION	AVAILABILITY AND/OR SPECIAL														
A-1															
DISTRIBUTION STAMP															
<div style="border: 1px solid black; padding: 10px; font-size: 2em; font-weight: bold;">20010116 031</div>															
DATE RECEIVED IN DTIC															
PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-FDAC															

HANDLE WITH CARE

Jerry Hansen

DRAFT

Work Plan for a Treatability Study in Support of Remediation by Natural Attenuation at Building 301



**Offutt Air Force Base
Omaha, Nebraska**

Prepared For

**Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas**

and

**55 CES/CEVR
Offutt Air Force Base
Omaha, Nebraska**

May 1996



**PARSONS
ENGINEERING SCIENCE, INC.**

1700 Broadway, Suite 900 • Denver, Colorado 80290

AQM01-04-0619

**DEFENSE TECHNICAL INFORMATION CENTER
REQUEST FOR SCIENTIFIC AND TECHNICAL REPORTS**

Title AFCEE Collection

1. Report Availability (Please check one box)

- ☒ This report is available. Complete sections 2a - 2f.
☐ This report is not available. Complete section 3.

**2a. Number of
Copies Forwarded**

1 each

2b. Forwarding Date

July/2000

2c. Distribution Statement (Please check ONE box)

DoD Directive 5230.24, "Distribution Statements on Technical Documents," 18 Mar 87, contains seven distribution statements, as described briefly below. Technical documents **MUST** be assigned a distribution statement.

- ☒ **DISTRIBUTION STATEMENT A:** Approved for public release. Distribution is unlimited.
- ☐ **DISTRIBUTION STATEMENT B:** Distribution authorized to U.S. Government Agencies only.
- ☐ **DISTRIBUTION STATEMENT C:** Distribution authorized to U.S. Government Agencies and their contractors.
- ☐ **DISTRIBUTION STATEMENT D:** Distribution authorized to U.S. Department of Defense (DoD) and U.S. DoD contractors only.
- ☐ **DISTRIBUTION STATEMENT E:** Distribution authorized to U.S. Department of Defense (DoD) components only.
- ☐ **DISTRIBUTION STATEMENT F:** Further dissemination only as directed by the controlling DoD office indicated below or by higher authority.
- ☐ **DISTRIBUTION STATEMENT X:** Distribution authorized to U.S. Government agencies and private individuals or enterprises eligible to obtain export-controlled technical data in accordance with DoD Directive 5230.25, Withholding of Unclassified Technical Data from Public Disclosure, 6 Nov 84.

2d. Reason For the Above Distribution Statement (in accordance with DoD Directive 5230.24)

2e. Controlling Office

HQ AFCEE

**2f. Date of Distribution Statement
Determination**

15 Nov 2000

3. This report is NOT forwarded for the following reasons. (Please check appropriate box)

- ☐ It was previously forwarded to DTIC on _____ (date) and the AD number is _____
- ☐ It will be published at a later date. Enter approximate date if known. _____
- ☐ In accordance with the provisions of DoD Directive 3200.12, the requested document is not supplied because:

Print or Type Name

Laura Peña

Telephone

210-536-1431

Signature

[Signature]

AD Number

M01-04-0619

DRAFT

**WORK PLAN FOR A TREATABILITY STUDY IN SUPPORT OF
REMEDICATION BY NATURAL ATTENUATION AT BUILDING 301
OFFUTT AIR FORCE BASE, NEBRASKA**

for

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS**

and

**55 CES/CEVR
OFFUTT AIR FORCE BASE
OMAHA, NEBRASKA**

May 1996

Prepared by

**Parsons Engineering Science, Inc.
1700 Broadway Suite 900
Denver, Colorado 80290**

TABLE OF CONTENTS

	Page
SECTION 1 - INTRODUCTION.....	1-1
1.1 SCOPE OF CURRENT WORK PLAN.....	1-3
1.2 BACKGROUND	1-5
1.2.1 Base and Site Operational History.....	1-5
1.2.2 Previous Investigations	1-7
1.2.2.1 Site Inspection	1-7
1.2.2.2 Remedial Investigation.....	1-11
1.2.2.3 Remedial Actions.....	1-13
SECTION 2 - DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT	2-1
2.1 DATA REVIEW	2-1
2.1.1 Topography, Surface Hydrology, and Climate.....	2-2
2.1.2 Overview of Geology and Hydrogeology	2-5
2.1.2.1 Regional Geology and Hydrogeology	2-5
2.1.2.2 B301 Geology and Hydrogeology.....	2-6
2.1.3 Nature and Extent of Contamination at B301	2-19
2.1.3.1 Soil Contamination	2-19
2.1.3.2 Surface Water and Sediment Contamination	2-20
2.1.3.3 Groundwater Contamination	2-21
2.1.3.4 Groundwater Geochemistry	2-24
2.1.4 Soil Total Organic Carbon Content	2-27
2.2 DEVELOPMENT OF CONCEPTUAL MODELS.....	2-27
2.2.1 RNA and Solute Transport Models	2-28
2.2.2 Biodegradation of CAHs.....	2-29
2.2.2.1 Electron Acceptor Reactions (Reductive Dehalogenation)	2-30
2.2.2.2 Electron Donor Reactions	2-32
2.2.2.3 Cometabolism.....	2-33
2.2.2.4 Behavior of Chlorinated Solvent Plumes.....	2-33
2.2.2.4.1 Type 1 Behavior	2-35
2.2.2.4.2 Type 2 Behavior	2-35
2.2.2.4.3 Type 3 Behavior	2-35
2.2.2.4.4 Mixed Behavior.....	2-36
2.2.3 Initial Conceptual Model	2-37

TABLE OF CONTENTS (CONTINUED)

	Page
SECTION 3 - COLLECTION OF ADDITIONAL DATA	3-1
3.1 UTILITY CLEARANCE, DIGGING PERMITS, AND WATER SOURCE VERIFICATION	3-4
3.2 MONITORING POINT/MONITORING WELL DRILLING, SOIL SAMPLING, AND INSTALLATION	3-5
3.2.1 Monitoring Point and Well Locations and Completion Intervals	3-5
3.2.2 Monitoring Point and Well Advancement and Installation Procedures ..	3-7
3.2.2.1 Monitoring Point Advancement, Soil Sampling, and Installation Procedures.....	3-7
3.2.2.1.1 PVC Monitoring Points	3-12
3.2.2.1.2 Stainless Steel Monitoring Points	3-13
3.2.2.1.3 Temporary Monitoring Points	3-15
3.2.2.2 Monitoring Well Advancement and Installation Procedures.....	3-15
3.2.3 Collection of Soil Samples for Field Screening and Laboratory Analysis During Monitoring Well/Point Drilling	3-18
3.2.4 Equipment Decontamination During Drilling and Soil Sampling Activities.....	3-18
3.2.5 Monitoring Point Development and Records	3-19
3.2.6 Location and Datum Survey	3-20
3.2.7 Water Level Measurements	3-22
3.3 GROUNDWATER SAMPLING.....	3-22
3.3.1 Preparation for Sampling	3-24
3.3.1.1 Equipment Cleaning.....	3-24
3.3.1.2 Equipment Calibration.....	3-25
3.3.2 Well and Monitoring Point Sampling Procedures.....	3-25
3.3.2.1 Preparation of Location.....	3-28
3.3.2.2 Water Level and Total Depth Measurements.....	3-28
3.3.2.3 Monitoring Well/Point Purging	3-28
3.3.2.4 Sample Extraction	3-29
3.3.2.5 Grab Sampling	3-29
3.3.3 Onsite Groundwater Parameter Measurement	3-29
3.3.3.1 Dissolved Oxygen Measurements	3-30
3.3.3.2 pH, Temperature, and Specific Conductance	3-30
3.3.3.3 Oxidation/Reduction Potentials.....	3-31
3.3.3.4 Alkalinity Measurements	3-31
3.3.3.5 Nitrate- and Nitrite-Nitrogen Measurements	3-31
3.3.3.6 Sulfate and Sulfide Sulfur Measurements.....	3-32

TABLE OF CONTENTS (CONTINUED)

	Page
3.3.3.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements....	3-32
3.3.3.8 Manganese Measurements.....	3-33
3.3.3.9 Carbon Dioxide Measurements.....	3-33
3.4 SURFACE WATER AND SEDIMENT SAMPLING	3-33
3.5 SAMPLE HANDLING FOR LABORATORY ANALYSIS.....	3-35
3.5.1 Sample Preservation.....	3-35
3.5.2 Sample Containers and Labels	3-35
3.5.3 Sample Shipment	3-36
3.5.4 Chain-of-Custody Control.....	3-36
3.5.5 Sampling Records	3-36
3.5.6 Fixed-Base Laboratory Analyses	3-37
3.6 SURFACE WATER FLOW RATE MEASUREMENTS	3-38
3.7 AQUIFER TESTING	3-39
3.7.1 Slug Tests	3-39
3.7.1.1 Definitions.....	3-39
3.7.1.2 Equipment	3-40
3.7.1.3 General Test Methods.....	3-40
3.7.1.4 Falling Head Test	3-41
3.7.1.5 Rising Head Test	3-43
3.7.1.6 Slug Test Data Analysis	3-44
SECTION 4 - QUALITY ASSURANCE/QUALITY CONTROL.....	4-1
SECTION 5 - DATA ANALYSIS AND REPORT	5-1
SECTION 6 - REFERENCES.....	6-1
APPENDICES	
A - Laboratory Analytical Data from WCC (1993 and 1996)	
B - Analytical Methods, Data Use, and Packaging Requirements for Environmental Samples	

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

No.	Title	Page
2.1	Summary of SI Monitoring Well Construction Details	2-7
2.2	Summary of RI Monitoring Well Construction Details	2-8
2.3	Summary of RI HydroPunch® and Soil Borehole Drilling	2-9
2.4	Summary of RI Geotechnical Test Results.....	2-10
2.5	RI Water Level Suvey Measurements	2-14
2.6	SI Hydraulic Conductivity Values	2-17
2.7	RI Hydraulic Conductivity Values per Hydrostratigraphic Unit.....	2-18
2.8	Summary of SI Water Quality Parameters.....	2-25
2.9	Summary of RI Monitoring Well Development.....	2-26
3.1	Analytical Protocol for Groundwater, Surface Water, Soil, and Sediment Samples	3-3
3.2	Summary of Proposed Monitoring Wells/Points.....	3-8
4.1	QA/QC Sampling Program	4-2
5.1	Example Report Outline	5-3

LIST OF FIGURES

No.	Title	Page
1.1	Base Location	1-6
1.2	Building 301 Layout	1-8
1.3	SI Sampling Locations.....	1-10
1.4	RI Sampling Locations.....	1-12
2.1	Regional Topography and Surface Drainage	2-3
2.2	Local Topography and Surface Drainage	2-4
2.3	SI Hydrogeologic Profile.....	2-11
2.4	Location of RI Hydrogeologic Profile B-B'	2-12
2.5	Groundwater Potentiometric Surface Elevations, March 1996	2-15
2.6	Anaerobic Reductive Dehalogenation	2-31
2.7	Aerobic Dehalogenation	2-34
3.1	Locations of Proposed Monitoring Points and Monitoring Wells	3-6
3.2	Cross-Section of Geoprobe®	3-9
3.3	Geologic Boring Log.....	3-11
3.4	Monitoring Well Installation Record	3-14
3.5	Monitoring Well Development Record.....	3-21
3.6	Groundwater Sampling Record	3-26
3.7	Aquifer Test Data Form	3-42

TABLE OF CONTENTS (CONTINUED)

LIST OF PLATES

No.	Title
1	RI Hydrogeologic Profile B-B'
2	Isoconcentration Map of TCE, July 1995 - April 1996
3	Isoconcentration Map of 1,2-DCE, July 1995 - April 1996
4	Hydrogeologic Profile B-B' with TCE Concentration in Groundwater

ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
μg/kg	micrograms per kilogram
μg/L	micrograms per liter
°C	degrees Celsius
55 CES/CEVR	55th Civil Engineering Squadron - Environmental Restoration Branch
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
B301	Building 301
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylene
CAH	chlorinated aliphatic hydrocarbon
CFR	Code of Federal Regulations
DCA	dichloroethane
DCE	dichloroethene
DO	dissolved oxygen
ES	Engineering-Science, Inc.
ft/day	feet per day
ft ² /day	square feet per day
ft/ft	foot per foot
ft/yr	feet per year
GC	gas chromatograph
HDPE	high density polyethylene
HSA	hollow stem auger
ID	inside diameter
LCS	laboratory control sample
LMB	laboratory method blank
LTM	long-term monitoring
MBP	Martin Bomber Plant
MEK	methyl ethyl ketone
mg/kg	milligrams per kilogram
mg/L	milligrams per liter

msl	mean sea level
NRMRL	National Risk Management Research Laboratory
OD	outside diameter
ORD	USEPA Office of Research and Development
ORP	oxidation reduction potential
OSWER	USEPA Office of Solid Waste and Emergency Response
PAH	polynuclear aromatic hydrocarbon
Parsons ES	Parsons Engineering Science, Inc.
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PES	Plains Environmental Services
PID	photoionization detector
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RAP	remedial action plan
redox	reduction/oxidation
RI	Remedial Investigation
RNA	remediation by natural attenuation
SAC	Strategic Air Command
SI	site investigation
SRW	Strategic Reconnaissance Wing
STRATCOM	Strategic Command
SVOC	semivolatile organic compound
SWMU	solide waste management unit
TCE	trichloroethene
TDS	total dissolved solids
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TS	treatability study
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
VC	vinyl chloride
VOC	volatile organic compound
WCC	Woodward-Clyde Consultants

SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering Science, Inc. (ES), presents the scope of work required for the collection of data necessary to conduct a treatability study (TS) for remediation of groundwater contaminated with chlorinated aliphatic hydrocarbons (CAHs) at the Building 301 (B301) Solid Waste Management Unit (SWMU) located at Offutt Air Force Base (AFB) in Bellevue, Nebraska. Hydrogeologic and groundwater chemical data collected under this program can be used to evaluate various remedial options; however, this work plan is oriented toward the collection of hydrogeologic data to be used as input into groundwater flow and solute transport models in support of remediation by natural attenuation (RNA) with long-term monitoring for restoration of groundwater contaminated with CAHs.

As used in this report, RNA refers to a management strategy that relies on natural attenuation mechanisms to remediate contaminants dissolved in groundwater and to control receptor exposure risks associated with contaminants in the subsurface. The United States Environmental Protection Agency Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER) define natural attenuation as:

The biodegradation, dispersion, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem.

As suggested by this definition, mechanisms for natural attenuation of CAHs include advection, dispersion, dilution from recharge, sorption, volatilization, and biodegradation. Of these processes, biodegradation is the only mechanism working to transform contaminants into innocuous byproducts. Contaminant destruction occurs through natural attenuation when indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without the addition of nutrients. Patterns and rates of natural attenuation can vary markedly from site to site depending on governing physical and chemical processes.

RNA is advantageous for the following reasons:

- Contaminants are transformed to innocuous byproducts (e.g., carbon dioxide and ethane), not just transferred to another phase or location within the environment;
- Current pump-and-treat technologies are energy intensive and generally not as effective in reducing residual contamination;
- The process is nonintrusive and allows continuing use of infrastructure during remediation;
- Current engineered remedial technologies may pose a greater risk to potential receptors than RNA (e.g., contaminants may be transferred into another medium during remediation activities); and
- RNA is far less costly than conventional, engineered remedial technologies.

As part of the B301 TS, the contaminant fate and transport modeling effort has three primary objectives: 1) predict the future extent and concentration of dissolved CAH contaminant plumes by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) assess the possible exposure of potential downgradient receptors to contaminant concentrations that exceed levels intended to be protective of human health and the environment; and 3) provide technical support for selection of RNA as the best remedial alternative at regulatory negotiations, as appropriate. The modeling efforts

for the B301 SWMU at Offutt AFB will involve completion of several tasks, which are described in the following sections.

This work plan was developed following discussions with representatives from the Air Force Center for Environmental Excellence (AFCEE), 55th Civil Engineering Squadron--Environmental Restoration Branch (55 CES/CEVR), and on a review of existing site characterization data. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993), and the site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and 55 CES/CEVR.

1.1 SCOPE OF CURRENT WORK PLAN

This project is part of a large, broad-based initiative being conducted by AFCEE in conjunction with the USEPA National Risk Management Research Laboratory (NRMRL) and Parsons ES. The intent of the RNA demonstration program is to develop a systematic process for scientifically investigating and documenting natural subsurface attenuation processes that can be factored into overall site remediation plans. For this reason, the work described in this work plan is directed toward the collection of data in support of demonstrating the effectiveness of RNA for CAHs dissolved in groundwater. Data required to develop alternative remedial strategies, should RNA prove not to be a viable remedial option at this facility, also will be collected under this program. A secondary goal of this multi-site initiative is to provide a database from multiple sites that demonstrates that natural processes of contaminant degradation often can reduce contaminant concentrations in groundwater to below acceptable cleanup standards before potential receptor exposure pathways are completed.

The specific objective for the demonstration at B301 is to investigate the degree to which CAHs dissolved in groundwater west of B301 are being remediated through natural attenuation so that this information can be used by the Base and its prime environmental contractor(s) to develop an effective groundwater remediation strategy. As a result, these demonstrations are not necessarily intended to fulfill specific federal

or state requirements regarding site assessments, remedial action plans (RAPs), or other such mandated investigations and reports.

This work plan describes the site characterization activities to be performed by personnel from Parsons ES and the Subsurface Protection and Remediation Division of the NRMRL (formerly the USEPA's Robert S. Kerr Environmental Research Laboratory) in support of the TS. Field activities will be performed to determine the effectiveness of RNA in remediating the dissolved CAH plume emanating from B301. The data collected during the TS will be used along with data from previous investigations to characterize contaminant and geochemical patterns at the site, and for use in the groundwater flow and solute transport models to make predictions of the future concentrations and extent of contamination.

Site characterization activities performed in support of the TS will include: 1) determination of preferential contaminant migration and potential receptor exposure pathways; 2) soil sample collection using a Geoprobe® or hollow-stem auger (HSA) drill rig; 3) groundwater monitoring well installation using an HSA or rotary drill rig; 4) groundwater monitoring point installation using a Geoprobe®, 5) groundwater sample collection, 6) soil and groundwater sample analysis; 7) collection and analysis of sediment and water samples from surface drainages; and 8) aquifer testing. The materials and methodologies to accomplish these activities are described herein.

Previously reported site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the groundwater flow and solute transport models. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site will be obtained from published literature and used for model input. Sensitivity analyses will be conducted for the parameters that are known to have the greatest influence on the model results, and where possible, the model will be calibrated using historical site data. Upon completion of the modeling, Parsons ES will provide technical assistance at regulatory negotiations to support RNA if the results of the modeling indicate that

this approach is warranted. If it is shown that RNA is not the most appropriate remedial option, Parsons ES will recommend an appropriate groundwater remedial technology on the basis of available data.

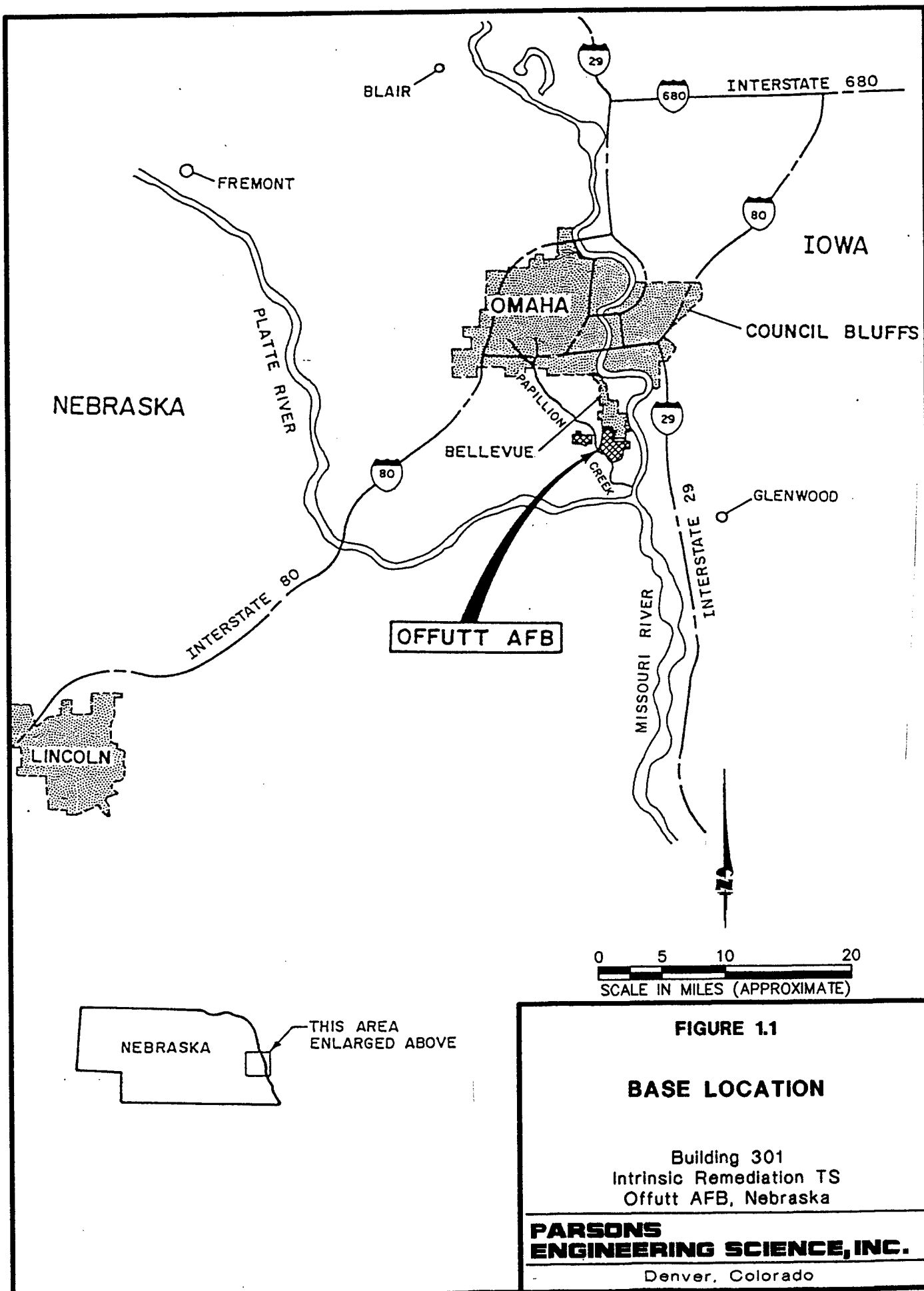
This work plan consists of six sections, including this introduction. Section 2 presents a review of available, previously reported, site-specific data and a preliminary conceptual model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and TS report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. There are two appendices to this work plan. Appendix A contains selected data from previous investigations performed at B301, and Appendix B contains a listing of containers, preservatives, packaging, and shipping requirements for soil, groundwater, surface water, and sediment samples.

1.2 BACKGROUND

The operational history of Offutt AFB and the B301 SWMU, and previous environmental investigations at B301, are summarized in the following paragraphs. Operational history information was derived primarily from WCC (1992a and 1993).

1.2.1 Base and Site Operational History

Offutt AFB occupies an area of approximately 2,750 acres in eastern Sarpy County, Nebraska. The Base is situated on an upland terrace east of the alluvial valley of Papillion creek. It is bordered by the cities of Bellevue and Omaha to the north, the city of Papillion to the west, and agricultural land along the Missouri and Platte rivers to the east and south, respectively (Figure 1.1). The Base was originally established by the US Army in 1888 as Fort Crook, and was continuously operated by the Army until transferred to the Air Force in 1948. From 1948 through 1992, the Base served as the headquarters for the Strategic Air Command (SAC). Since 1992, the Base has served as the Strategic Command (STRATCOM) Headquarters. The Base presently



employs approximately 11,000 military and civilian personnel [Woodward-Clyde Consultants (WCC), 1992a].

B301, shown on Figure 1.2, was constructed in 1941 as a bomber manufacturing facility for the armed forces during World War II. The facility, known as the Martin Bomber Plant (MBP), had 1,200,000 square feet of floor space and was in full production by June 1942. The MBP was used to produce hundreds of B-26 and B-29 bombers through the end of World War II. After the war, manufacturing machinery was stored and shipped to other plants for aircraft production. Beginning in June 1959, the MBP was used as a guided missile assembly facility, a function which ceased in December 1965 with the deactivation of the 549th Strategic Missile Squadron.

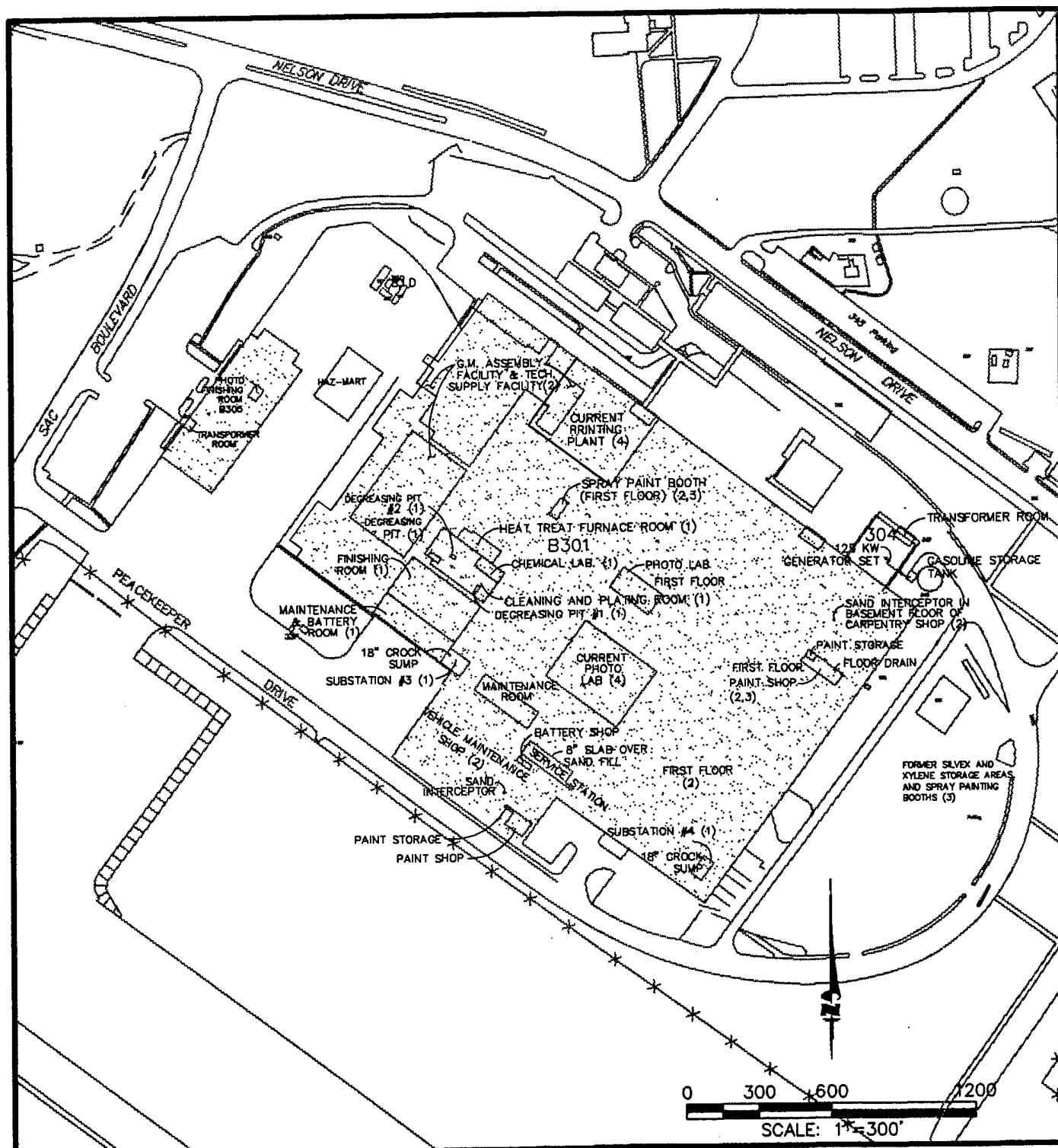
Currently, B301 is the home of the 55th Strategic Reconnaissance Wing (SRW) Transportation Squadron, the 55th SRW Supply Squadron, the 55th CES, the 3428th Technical Training Squadron, the 544th Target Materials Squadron, the 544th Intelligence Exploitation Squadron, and the 1000th Satellite Operations Group. Offutt AFB services currently provided in B301 include a barber shop, a printing plant and publication distribution office, a photographic laboratory, and the Education Services Branch. Recreational facilities within B301 currently include tennis courts, a wood hobby shop, and indoor bowling.

1.2.2 Previous Investigations

A site inspection (SI) and remedial investigation (RI) have been performed at the B301 SWMU. Each of these investigations is described in the following paragraphs.

1.2.2.1 Site Inspection

An SI at B301 was performed by WCC (1993) during September through December 1991 to collect and evaluate the data needed to confirm the presence or absence of contamination at the B301 SWMU. Specific goals of the SI were:



BUILDING 301 NOTES

- (1) Potential Source Area from 1940's
- (2) Potential Source Area from 1950's and 1960's
- (3) Potential Source Area from 1980's
- (4) Current Potential Source Area

FIGURE 1.2

BUILDING 301 LAYOUT

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

- To identify and evaluate the presence or absence of potential soil, sediment, and groundwater contamination;
- To identify and evaluate the presence or absence of potential contamination in storm and wastewater discharges from B301 and at the Papillion Creek stormwater outfall; and
- To complete a preliminary hydrogeologic evaluation.

To fulfill these objectives, one deep and six shallow groundwater monitoring wells were installed, developed, purged, and sampled; three soil samples from each of the shallow well boreholes were chemically analyzed at a laboratory; four surface water and six sediment samples were collected and analyzed at a laboratory; slug tests were performed in four monitoring wells; and soil samples were collected for geotechnical testing. The results of the SI are reported by WCC (1993), and SI sampling locations are shown on Figure 1.3.

The groundwater and surface water samples were analyzed for Title 40, Code of Federal Regulations, Section 264 (40 CFR 264) Appendix IX volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), organochlorine pesticides and polychlorinated biphenyls (PCBs), herbicides, total petroleum hydrocarbons (TPH), total recoverable metals, cyanide, sulfide, and general water quality parameters [total dissolved solids (TDS), alkalinity, chloride, sulfate, nitrate, and nitrite]. Several VOCs were detected in the surface water and groundwater samples collected at the B301 SWMU, including chloroform, trichloroethene (TCE), 1,2-dichloroethene (DCE), carbon tetrachloride, bromodichloromethane, dibromochloromethane, and trichlorofluoromethane. Maximum detected concentrations of each individual VOC did not exceed 40 micrograms per liter ($\mu\text{g/L}$). Trace concentrations of acetone and methylene chloride were detected in one sample, but were considered to be laboratory contaminants. With the exception of the SVOC bis(2-ethylhexyl)phthalate, which also was considered to be a laboratory contaminant, no

SVOCs, pesticides, herbicides, PCBs, or petroleum hydrocarbons were detected in groundwater samples. A total pesticide concentration of 0.242 µg/L and a TPH concentration of 36.1 µg/L were detected in one of the four surface water samples. No significant soil contamination was found in the soil borehole samples collected around the facility (WCC, 1993).

The SI concluded that the former operations at the southwest part of the B301 SWMU had the greatest potential for releases that may have impacted the environment. The suspected release(s) of solvents such as TCE may have originated at the former paint building (Facility 305) or the former cleaning and chemical rooms that were located in the southwestern corner of B301 (Figure 1.2). These areas were used during the aircraft and missile assembly period of operations (1940's).

1.2.2.2 Remedial Investigation

An RI for B310 is currently being performed by WCC (1996). Between July and December 1995, 194 groundwater samples were collected at 91 locations using a Geoprobe® to define the nature, magnitude, and vertical and lateral extent of groundwater contamination (Figure 1.4). This task was performed by WCC's subcontractor, Plains Environmental Services (PES) of Salina, Kansas. The samples were analyzed onsite using a gas chromatograph (GC); target analytes included 1,1-DCE, *cis*-1,2-DCE, and TCE. In addition, 10 groundwater samples were collected from five boreholes using a HydroPunch® in August 1995 (Figure 1.4). These samples were analyzed for a more complete list of VOCs at a laboratory using USEPA Method SW8021A.

The RI sampling results documented the presence of a CAH plume approximately 2,700 feet long and 700 feet wide migrating toward the west from the B301 area in the shallow groundwater aquifer. The plume had migrated approximately 1,000 feet beyond the downgradient Base boundary. The plume depth ranged from about 50 to 60 feet below ground surface (bgs) in the upland area near B301 (where the water table is

approximately 50 to 80 feet bgs) to 5 to 10 feet bgs in the alluvial valley west of B301 (where the water table is less than 10 feet bgs). The plume thickness ranged from 10 to 30 feet. TCE was the analyte that exhibited the greatest lateral extent and concentrations. The source of contamination was initially thought to be two former acid-neutralization pits located west of the northwest corner of B301. However, groundwater sampling results suggested that either the pit locations were different than shown on design drawings, or they are not the primary contamination sources. Based on the RI results, the possible source(s) of the groundwater contaminant plume may be beneath B301 in the vicinity of the northwestern corner of the building.

The groundwater sampling results described above were used to locate 11 new monitoring wells that were installed in December 1995 and March 1996 (Figure 1.4). The wells were sampled in April 1996, and analyzed for Appendix IX VOCs using USEPA Method SW8240. Detected analytes included TCE, 1,2-DCE, carbon tetrachloride, tetrachloroethene (PCE), and toluene. TCE was the most frequently detected analyte and generally had the most elevated concentrations (WCC, 1996).

A total of nine soil samples were collected from four of the new RI wells and analyzed for Appendix IX VOCs and/or TOC. Low concentrations [not exceeding 12 micrograms per kilogram ($\mu\text{g}/\text{kg}$)] of several aromatic and chlorinated VOCs were detected. In addition, 11 soil samples were collected from six soil boreholes for geotechnical testing.

Six surface water and four sediment samples were collected from the surface drainages located east and west of Fort Crook Road (Figure 1.4). Low concentrations of TCE and 1,2-DCE (less than 20 $\mu\text{g}/\text{L}$) were detected, indicating that contaminated groundwater discharges into surface water.

1.2.2.3 Remedial Actions

Radian Corporation (Radian) was tasked with pilot-testing a dual-phase (groundwater and soil vapor) extraction system near the northwestern corner of B301, where the most elevated CAH concentrations were detected in the groundwater. This pilot test was performed in May 1996.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Existing site-specific data were reviewed and used during preparation of this work plan to develop preliminary conceptual models for the groundwater flow and contaminant transport regimes for the B301 SWMU. These conceptual models guided the selection of sampling locations and analytical data requirements needed to support the modeling effort and to evaluate potential remediation options, including RNA. Section 2.1 presents a synopsis of available site data. Section 2.2 presents the preliminary conceptual groundwater flow and solute transport models that were developed based on these data.

2.1 DATA REVIEW

The following sections were based upon review of data from the following sources:

- Engineering Evaluation/Cost Analysis Workplan in Support of the Intrinsic Remediation (Natural Attenuation) Option for Tank 349 and Fire Protection Area 3 (Parsons ES, 1994);
- Treatability Study in Support of Intrinsic Remediation for Fire Protection Area 3 (Parsons ES, 1995);
- Site Inspection Report for B301 (WCC, 1993);
- Unpublished RI data for B301 received from WCC (1996); and
- Groundwater Monitoring Program 1991-1992 (WCC, 1992b).

2.1.1 Topography, Surface Hydrology, and Climate

The Base is located in the dissected till plains section of the Central Lowland Physiographic Province of the Interior Plains, a region characterized by large, gently sloping plains, slight local relief, and relatively low altitudes of 500 to 2,000 feet above mean sea level (MSL). Base elevations range from approximately 960 to 1,140 feet msl [US Geological Survey (USGS), 1984a and 1984b]. Regional and local ground surface topography and surface water features are shown on Figures 2.1 and 2.2, respectively. The sites are situated on a dissected Pleistocene alluvial terrace remnant of the Missouri River with moderately sloping rolling hills (WCC, 1992b). The area immediately surrounding B301 was leveled prior to the original construction in 1941. To the west of B301, the ground surface slopes steeply downward into the Papillion Creek alluvial valley; downward slopes that are less steep are present to the south and east of the building (Figure 2.2). The ground surface rises to the north and northeast from the B301 SWMU to the Offutt AFB boundary (WCC, 1993).

Major surface water features in the area include the Missouri River, located 0.5 to 2 miles east of the Base boundary, and the Platte River, located approximately 3 miles south of the Base boundary. Papillion Creek flows between the Cape Hart Housing Area and the main body of the Base to its confluence with the Missouri River southeast of the Base (Figure 1.1). The Base lake occupies the southeastern corner of the Base (Figure 2.1). Surface water runoff at B301 is collected by storm sewers and drainage ditches. Approximately 25 percent of the storm sewers discharge to drainage ditches near the western boundary of the Base, where the water evaporates, infiltrates, or flows downstream. The remaining storm sewers transmit runoff to the south boundary of Offutt AFB, where they discharge to Papillion Creek (WCC, 1993). A northward-flowing drainage ditch is present at the Base boundary immediately west of B301 (Figure 2.2).

The climate is continental, characterized by cold winters, hot summers, and moderate rainfall. Average daily maximum temperatures range from 29 degrees Fahrenheit (°F) in January to 87°F in July. Precipitation occurs primarily as snow,

steady rainstorms during spring, as scattered thunderstorms (often with high wind) during late spring and summer, and as snow during the winter. The mean annual Base precipitation is approximately 31.9 inches, with about 75 percent of the annual precipitation occurring between April and September. The 1-year, 24-hour rainfall event is reported to be 2.5 inches (Black & Veatch, 1990).

2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Regional Geology and Hydrogeology

Regionally, bedrock consists of interbedded shale and limestone of Pennsylvanian age. In the rolling upland areas, bedrock is overlain by as much as 200 feet of glacial and periglacial deposits. The glacial deposits consist of thick sequences of clay-rich till with thin and thick interbeds of sand and gravel outwash. A mantle of periglacial loess at least 25 feet thick overlies most of the glacial till in the upland areas (WCC, 1992b).

Lowland areas are occupied by alluvial and glacial fluvial sediments that range in thickness from less than 10 feet near the upland areas to greater than 100 feet near the Missouri River. The glacial fluvial deposits consist of fine to coarse sand and gravel, grading upward to alluvial fine sand and silty sand and covered by up to 20 feet of alluvial organic silt and clay. In some areas of the Base, fill materials, typically loose sands, are present at thicknesses of up to 10 feet (WCC, 1992b).

Remnants of Pleistocene alluvial terraces occupy valley sides and former drainageways of major streams in eastern Nebraska. Most of these terraces are composed of fine-grained alluvium (fine sand and silt), and all of them are capped by Peorian loess. Much of the city of Bellevue and part of the Base occupy a dissected Pleistocene terrace remnant of the Missouri River (WCC, 1993).

The groundwater surface generally reflects the surface topography. Hydraulic gradients in the upland areas are relatively steep, hydraulic conductivities are low, and depth to groundwater can exceed 50 feet. In lowland areas, hydraulic gradients are relatively flat, hydraulic conductivities are higher, and the depth to groundwater is

frequently 10 feet or less. Hydraulic conductivities measured at the Base have ranged from 0.03 foot per day (ft/day) in shallow fill and alluvial clay/silt to 270 ft/day in deep glacial outwash sand. Hydraulic conductivities in the deeper groundwater zones are nearly always higher than near the groundwater surface. The highest measured shallow hydraulic conductivity was 9.5 ft/day in alluvial silty sand. Regionally, groundwater flow is predominantly toward Papillion Creek and the Missouri River. Locally, groundwater flow may be influenced by site features such as drainage ditches, paved surfaces, and buried utilities (WCC, 1992b).

2.1.2.2 B301 Geology and Hydrogeology

Site-specific geologic and hydrogeologic information was obtained primarily from WCC (1993) and unpublished RI data collected by WCC (1996). Construction details for monitoring wells installed during the SI and RI are summarized in Tables 2.1 and 2.2, respectively. Table 2.3 contains a summary of HydroPunch® boreholes and soil boreholes drilled by WCC during the RI. Table 2.4 summarizes soil geotechnical test results obtained during the RI. Geologic and hydrogeologic data collected during the SI were used to construct a hydrogeologic profile. The profile location and profile are shown on Figures 2.2 and 2.3, respectively. Another hydrogeologic profile extending to the west from B301 was constructed using data collected during the subsequent RI. The RI profile line and profile are shown on Figure 2.4 and Plate 1, respectively. Plates are located at the end of this document.

Up to approximately 13 feet of fill soil has been placed in the immediate vicinity of B301. Approximately 1 to 3 feet of fill material also is reportedly present west of the upland terrace along the terrace slope and in the Papillion Creek alluvial valley. The fill beneath the upland terrace surface consists of a very stiff, light-brown, low plastic, silty clay. The fill overlies either a stiff, black, low plastic, silty clay (topsoil) or a stiff to very stiff, light to reddish brown, low plastic, silty clay (Peoria and Loveland Loess). The combined thickness of the Peoria and Loveland Loess, which are undifferentiated in Plate 1, is up to 50 feet in the immediate vicinity of B301, and

TABLE 2.1
SUMMARY OF SI MONITORING WELL
CONSTRUCTION DETAILS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Well Number	Completion Date	Constructed By	Well Material	Elevation (feet MSL)		Depths ⁴ (feet bgs) and Elevations (feet MSL)							
				TOC ¹	GS ²	Depth to A	EL ³ A	Depth to B	EL ³ B	Depth to C	EL ³ C	Depth to D	EL ³ D
B301-MW1	09-20-91	WCC	2" ID PVC	1061.29	1058.87	43.5	1015.4	47.0	1011.9	62.0	996.9	62.5	996.4
B301-MW2	09-24-91	WCC	2" ID PVC	1067.40	1064.78	46.5	1018.3	49.5	1015.3	64.5	1000.3	65.0	999.8
B301-MW2D	10-14-91	WCC	2" ID PVC	1067.00	1064.59	99.0	965.6	102.0	962.6	107.0	957.6	107.5	957.1
B301-MW3	09-26-91	WCC	2" ID PVC	1069.24	1066.64	51.0	1015.6	54.0	1012.6	69.0	997.6	69.5	997.1
B301-MW4	10-08-91	WCC	2" ID PVC	1068.79	1066.18	47.0	1019.2	50.0	1016.2	65.0	1001.2	65.5	1000.7
B301-MW5	10-10-91	WCC	2" ID PVC	1051.58	1051.91	36.0	1015.9	39.0	1012.9	54.0	997.9	54.5	997.4
B301-MW6	10-08-91	WCC	2" ID PVC	1054.41	1054.72	37.0	1017.7	40.0	1014.7	55.0	999.7	55.5	999.2

¹ TOC = Top of casing, surveyed by WCC, 1991

² GS = Ground Surface, surveyed by WCC, 1991

³ EL = Elevation

⁴ Depth to A = Distance from ground surface to top of filter pack

Depth to B = Distance from ground surface to top of well screen

Depth to C = Distance from ground surface to bottom of well screen

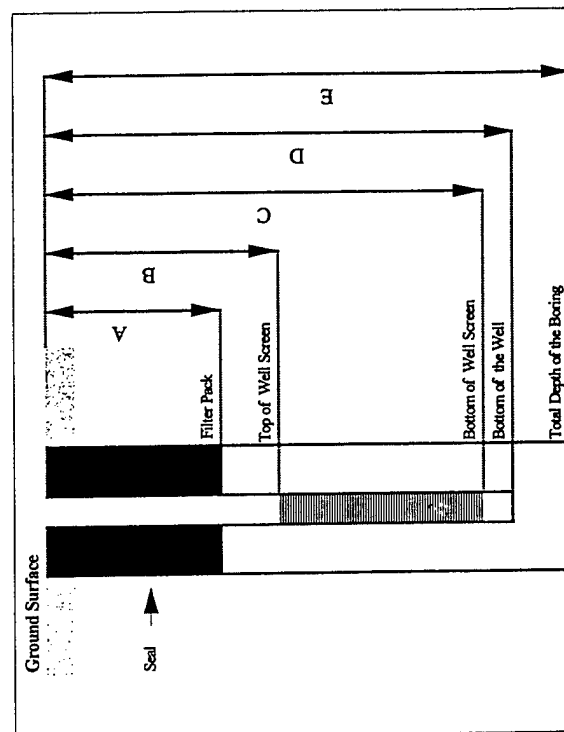
Depth to D = Distance from ground surface to bottom of well

TABLE 2.2
SUMMARY OF RI MONITORING WELL
CONSTRUCTION DETAILS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Well Number	Date Completed	Constructed By	Saturated Unit	Elevation (ft MSL)		Depth (ft bgs) and Elevations (ft MSL) of Monitoring Well Details									
				TOC	GS	Depth to A	Elev A	Depth to B	Elev B	Depth to C	Elev C	Depth to D	Elev D	Depth to E	Elev E
B301-MW7S	12/18/95	WC	Loess	1055.07	1055.5	43.0	1012.5	46.0	1009.5	50.5	1005.0	51.1	1004.4	53.0	1002.5
B301-MW7I	12/15/95	WC	Outwash	1055.26	1055.6	62.0	993.6	65.5	990.1	70.0	985.6	70.8	984.8	72.0	983.6
B301-MW7D	12/7/95	WC	Outwash	1055.25	1055.7	86.2	969.5	90.1	965.6	94.6	961.1	95.1	960.6	97.0	958.7
B301-MW8I	3/18/96	WC	Outwash	1015.12	1012.9	33.0	979.9	35.5	977.4	40.0	972.9	40.7	972.2	41.5	971.4
B301-MW9S	3/14/96	WC	Alluvial Silt/Clay	992.01	989.4	3.5	985.9	4.5	984.9	14.0	975.4	14.7	974.7	16.0	973.4
B301-MW9I	3/14/96	WC	Alluvial Silt/Clay	992.01	989.4	33.0	956.4	35.5	953.9	40.0	949.4	40.7	948.7	41.5	947.9
B301-MW10	3/12/96	WC	Alluvial Silt/Clay	981.27	979.0	5.5	973.5	7.5	971.5	17.0	962.0	17.7	961.3	18.0	961.0
B301-MW11	3/13/96	WC	Alluvial Silt/Clay	976.85	974.5	5.5	969.0	7.5	967.0	17.0	957.5	17.7	956.8	18.0	956.5
B301-MW12	3/13/96	WC	Alluvial Silt/Clay	981.37	979.1	5.5	973.6	7.5	971.6	17.0	962.1	17.7	961.4	18.0	961.1
B301-TW1	3/12/96	WC	Alluvial Silt/Clay	983.64	980.8	5.0	975.8	7.5	973.3	17.0	963.8	17.7	963.1	18.0	962.8
B301-TW2	3/12/96	WC	Alluvial Silt/Clay	976.36	973.5	4.0	969.5	7.5	966.0	17.0	956.5	17.7	955.8	18.0	955.5

MONITORING WELL DETAIL LEGEND



NOTE

- R = feet
- bgs = below ground surface
- TOC = top of casing
- GS = ground surface
- MSL = mean sea level
- ID = inner diameter
- PVC = polyvinylchloride
- SS = stainless steel

Source: WCC, 1996.

TABLE 2.3
SUMMARY OF RI HYDROPUNCH® AND SOIL BOREHOLE DRILLING
BUILDING 301
INTRINSIC REMEDIATION TS
OFFUTT AIR FORCE BASE, NEBRASKA

Borehole ID	Date Completed	Drilled by	Ground Surface Elevation (feet msl) ^{a/}	Total Borehole Depth (feet bgs) ^{b/}	Groundwater Sample Depth (feet bgs)
HP-1 ^{c/}	8/3/95	WCC ^{d/}	1044.65	90	70,86
HP-2	8/8/95	WCC	1059.2	109	59,75,90
HP-3	8/18/95	WCC	1044.97	89	72
HP-4	8/29/95	WCC	1054.57	81	66,80
HP-4A	8/25/95	WCC	1054.33	66	NA ^{e/}
HP-5	8/29/95	WCC	1055.48	66	66
SB-1 ^{f/}	8/11/95	WCC	1056.95	100	NA
SB-2	8/14/95	WCC	1055.34	81	NA
SB-3	8/17/95	WCC	989.33	70	NA
SB-4	8/21/95	WCC	992.33	42	NA
SB-5	8/24/95	WCC	1011.35	109.5	NA
SB-6	8/31/95	WCC	1000	50	NA
SB-7	10/19/95	WCC	980	78	NA
SB-8	10/20/95	WCC	980	62	NA
SB-9	10/23/95	WCC	980	62	NA

^{a/} feet msl = feet above mean sea level.

^{b/} feet bgs = feet below ground surface.

^{c/} HP = HydroPunch borehole

^{d/} WCC = Woodward-Clyde Consultants

^{e/} NA - Not applicable

^{f/} Soil borehole

TABLE 2.4
SUMMARY OF RI GEOTECHNICAL
TEST RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Boring Number	Sample Depth (ft)	Unified Soil Classification	Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	% Passing No. 200 Sieve
B301-SB1	88-90	SP-SM				8
B301-SB1	98-100	CL	15	35	14	
B301-SB2	77-79	SP-SM				5
B301-SB3	58-60	SC TO SM				23
B301-SB5	38-40	SP				5
B301-SB5	48-50	GP				3
B301-SB7	40-42	ML	34	37	25	99
B301-SB7	50-52	SP				5
B301-SB7	70-72	SP-SM				9
B301-SB9	30-32	CH	36	71	29	
B301-SB9	48-50	ML	38	35	29	

decreases in thickness to the west, finally pinching out near the eastern edge of the Papillion Creek alluvial valley. The loess overlies a sequence of glaciofluvial sediments and glacial outwash that ranges up to at least 50 feet in thickness. These glacial sediments consist mainly of well-sorted sand and silty sand. Relatively thin layers (up to approximately 5 feet thick) of clay-rich glacial till are present within the coarser-grained outwash deposits. The glaciofluvial sediments overlie clay-rich glacial till, which is in turn underlain by limestone.

As shown on Plate 1, the loess and glacial outwash deposits pinch out to the west of B301 near the Offutt AFB boundary and the base of the upland terrace. The subsurface west of B301 in the Papillion Creek valley is underlain primarily by clay, silty clay, and clayey silt of alluvial origin. Two 8- to 10-foot-thick sand layers encased within the alluvial clays and silts were penetrated by borehole SB7 (Plate 1). Available data indicate that the alluvial section west of the Base boundary is approximately 50 to 70 feet thick. The alluvium is underlain by glacial till.

As shown on Figure 2.3 and Plate 1, the depth to groundwater in the immediate vicinity of B301 is approximately 45 to 60 feet bgs. The depth to groundwater decreases toward the west as a result of the steep decline in ground surface elevation between the upland terrace and the alluvial valley, decreasing to between 3 and 10 feet bgs near and west of the Base boundary.

Table 2.5 contains groundwater elevation data collected by WCC in March and April 1996, and Figure 2.5 depicts a potentiometric surface map for the shallow portions of the groundwater system constructed using March 1996 data. Figure 2.5 indicates that the groundwater flow direction is toward the west. The lateral hydraulic gradient beneath the upland terrace was approximately 0.002 foot per foot (ft/ft), steepening to nearly 0.03 ft/ft beneath the terrace slope to the west of B301. Beneath the alluvial valley west of Fort Crook Road, the gradient lessens to approximately 0.008 ft/ft.

TABLE 2.5
RI WATER LEVEL
SURVEY MEASUREMENTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Monitoring Well Number	TOC Elevation (ft. MSL)	3/29/96		4/24/96	
		Depth to Water (ft. BTOC)	Water Elevation (ft. MSL)	Depth to Water (ft. BTOC)	Water Elevation (ft. MSL)
B301-MW1	1061.29	53.12	1008.17	53.12	1008.17
B301-MW2S	1067.40	58.13	1009.27	58.26	1009.14
B301-MW2D	1067.00	57.76	1009.24	57.75	1009.25
B301-MW3	1069.24	59.52	1009.72	59.54	1009.70
B301-MW4	1068.79	56.93	1011.86	56.89	1011.90
B301-MW5	1051.57	40.90	1010.67	40.95	1010.62
B301-MW6	1054.41	43.71	1010.70	43.8	1010.61
B301-MW7S	1055.07	45.73	1009.34	45.73	1009.34
B301-MW7I	1055.26	47.18	1008.08	45.79	1009.47
B301-MW7D	1055.25	45.89	1009.36	45.87	1009.38
B301-MW8I	1015.12	19.26	995.86	19.2	995.92
B301-MW9S	992.01	6.30	985.71	6.06	985.95
B301-MW9I	992.01	6.39	985.62	6.13	985.88
B301-MW10S	981.27	8.28	972.99	8.25	973.02
B301-MW11S	976.85	5.60	971.25	5.23	971.62
B301-MW12S	981.37	8.26	973.11	8.05	973.32
B301-TW1	983.64	8.04	975.60	8.91	974.73
B301-TW2	976.36	6.04	970.32	5.63	970.73
362-MW13	1045.42	25.76	1019.66	NA	
MW301-1*	1063.64	54.31	1009.33	NA	
MW305-1*	1043.42	34.96	1008.46	NA	
MW305-2*	1043.85	35.39	1008.46	NA	
MW305-3*	1042.89	34.62	1008.27	NA	
MW305-4*	1042.63	34.12	1008.51	NA	
MW305-5*	1058.94	49.97	1008.97	NA	
MW337-1*	1070.04	60.57	1009.47	NA	

*Installed by Terracon Environmental, Inc.

Vertical hydraulic gradients were calculated using groundwater elevation data for three well clusters collected in March and April 1996 by WCC. The well clusters included B301-MW2S/2D, B301-MW7S/7I/7D, and B301-MW9S/9D. The vertical gradients were calculated by dividing the water level elevation difference between two clustered wells by the distance between the midpoints of the saturated portions of the well screens. Well cluster B301-MW7S/7I/7D is located on the upland terrace near the northwest corner of B301. A downward vertical gradient of 0.065 ft/ft was present between the shallow and intermediate well screen intervals in March 1996, and an upward gradient of 0.007 ft/ft was present in April 1996. The gradients between the intermediate and deep screen intervals were reversed; the March 1996 gradient was upward with a magnitude of 0.052 ft/ft, and the April gradient was downward with a magnitude of 0.004 ft/ft. Well cluster MW9S/9I is located near the base of the terrace slope just east of Fort Crook Road. Measured vertical hydraulic gradients were downward in both March and April 1996, with magnitudes of 0.002 to 0.003 ft/ft. Well cluster MW2S/2D is located in the alluvial valley west of Fort Crook Road. A slight downward gradient (0.0006 ft/ft) was measured in March 1996, and an upward gradient (0.002 ft/ft) was measured in April 1996.

During SI and RI field activities, slug tests were performed in 14 monitoring wells to provide estimates of the hydraulic conductivity of the water-bearing zones (WCC, 1993 and 1996) (Tables 2.6 and 2.7). The geometric mean hydraulic conductivity values obtained during the RI for loess (3 tests), alluvial clay and silt (5 tests), glacial outwash sand with clay (1 test), and glacial outwash sand and gravel (3 tests) were 0.36 ft/day, 0.75 ft/day, 1.53 ft/day, and 7.41 ft/day, respectively. These values are within the range of hydraulic conductivity values of 0.06 to 17 ft/day obtained during the SI.

The advective velocity of groundwater in the direction parallel to groundwater flow is given by:

$$v = \frac{K}{n_e} \frac{dH}{dL}$$

TABLE 2.6
SI HYDRAULIC
CONDUCTIVITY VALUES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Monitoring Well	Soil Type ¹ (USC)	Screened ² Interval	Hydraulic Conductivity ³		
			cm/sec	ft/day	gpd/ft ²
B301-MW2D	SP	D	6.0×10^{-3}	17	130
B301-MW3	CL/SC/SP/SM	S	8.8×10^{-5}	0.25	1.9
B301-MW4	CL	S	2.1×10^{-5}	0.06	0.45
B301-MW6	CL/SC	S	4.2×10^{-5}	0.12	0.90

- 1 Dominant lithology of the screened interval, based on visual-manual description (Boring Logs, Appendix A).
- 2 Vertical placement of well screen: S = SHALLOW - intercepts the water table, I = INTERMEDIATE - screened within the aquifer, D = DEEP - screened at base of aquifer.
- 3 Hydraulic Conductivities were calculated from rising head slug tests.

TABLE 2.7
RI HYDRAULIC CONDUCTIVITY VALUES
PER HYDROSTRATIGRAPHIC UNIT

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Well Number	Screen Interval Elevation (ft. amsl)	Hydraulic Conductivity			Comments
		(k)			
		ft/day	cm/sec	gpd/ft ²	
Loess					
B301-MW7S	1009.5 to 1005.0	0.45	1.59x10 ⁻⁴	3.37	Well installed for SI Well installed & slug tested for SI
B301-MW1	1011.9 to 996.9	0.99	3.49x10 ⁻⁴	7.41	
B301-MW6	1014.7 to 999.7	0.12	4.2x10 ⁻⁵	0.9	
	Geometric Mean	0.36	1.32x10 ⁻⁴	2.82	
Alluvial clay/silt					
B301-MW9S	984.9 to 975.4	1.92	6.78x10 ⁻⁴	14.36	
B301-MW9I	953.9 to 949.4	1.97	6.95x10 ⁻⁴	14.74	
B301-MW10S	971.5 to 962.0	0.1	3.53x10 ⁻⁵	0.75	
B301-MW11S	967.0 to 957.5	0.54	1.91x10 ⁻⁴	4.04	
B301-MW12S	971.6 to 962.1	1.18	4.17x10 ⁻⁴	8.83	
	Geometric Mean	0.75	2.66x10 ⁻⁴	5.63	
Glacial outwash sand w/clay					
B301-MW7I	990.1 to 985.6	1.52	5.37x10 ⁻⁴	11.37	
	Geometric Mean	1.52	5.37x10 ⁻⁴	11.37	
Glacial outwash sand/gravel					
B301-MW7D	965.6 to 961.1	2.25	7.94x10 ⁻⁴	16.83	Well installed & slug tested for SI
B301-MW8I	977.4 to 972.9	10.62	3.75x10 ⁻³	78.69	
B301-MW2D	962.6 to 957.6	17	6.0x10 ⁻³	130	
	Geometric Mean	7.41	2.61x10 ⁻³	55.63	

Source: WCC, 1996.

Where: \bar{v} = Average advective groundwater velocity (seepage velocity)
[L/T]

K = Hydraulic conductivity [L/T]

dH/dL = Lateral Hydraulic gradient [L/L]

n_e = Effective porosity.

As stated earlier in this section, the lateral hydraulic gradient in the study area ranges from 0.002 ft/ft beneath the terrace to 0.03 ft/ft beneath the terrace slope to 0.008 ft/ft beneath the alluvial valley. The effective porosities of the loess (silty clay), glacial outwash (sand), and alluvial silt and clay are estimated to be 0.15, 0.25, and 0.10, respectively based on data from Johnson (1967) and Walton (1988). Using these data, the advective groundwater flow velocity in the outwash deposits beneath the upland terrace and terrace slopes is estimated to range from 0.01 to 0.9 ft/day [4 to 328 feet per year (ft/yr)], with the higher velocities occurring beneath the slopes. The advective velocity within the loess deposits beneath the terrace and slopes is estimated to range from 0.003 to 0.04 ft/day (1 to 15 ft/yr). The average velocity within the alluvial silts and clays beneath the adjacent valley is estimated to be approximately 0.06 ft/day (22 ft/yr). However, locally higher velocities are possible within the alluvial sand zones present in the alluvial valley.

2.1.3 Nature and Extent of Contamination at B301

The following sections are derived from information presented in the SI report for the B301 SWMU (WCC, 1993) and from unpublished RI data collected by WCC (1996).

2.1.3.1 Soil Contamination

During the SI, three soil samples were collected from each of six soil boreholes (Figure 1.3) and analyzed for Appendix IX VOCs, SVOCs, organochlorine pesticide and PCBs, TPH, total metals, and cyanide. Analytical results for soils are contained in

Appendix A. With the exception of one 37- $\mu\text{g/kg}$ detection of 2-butanone [methyl ethyl ketone (MEK)] at borehole MW1, located adjacent to Building 305, all VOC detections were below reporting limits and are therefore estimated values (flagged with a "J" qualifier). MEK is potentially a laboratory artifact and may not be SWMU-related. PCE was detected in one sample at 1.6J $\mu\text{g/kg}$, 1,2-dichloroethane (DCA) was detected in seven samples at concentrations ranging from 1.4J to 5.1J $\mu\text{g/kg}$, toluene was detected in four samples at concentrations ranging from 1.7J to 4.1J $\mu\text{g/kg}$, and acrylonitrile (reportedly a potential laboratory artifact), was detected in one sample at 2.9J $\mu\text{g/kg}$.

A total of five soil samples collected during the RI were analyzed for Appendix IX VOCs. These samples were collected from the borehole for monitoring well MW7I at depths ranging from 25 to 58 feet bgs. The groundwater sample from this well, located near the northwest corner of B301, contained the highest TCE concentration detected in the study area (25,000 $\mu\text{g/L}$). TCE was detected in three of the five MW7I samples at concentrations ranging from 1.8 $\mu\text{g/kg}$ to 12 $\mu\text{g/kg}$ (see Appendix A). Low levels of the VOCs benzene, methylene chloride, and toluene (not exceeding 10 $\mu\text{g/kg}$ in concentration) also were detected in each of the soil samples. The SI and RI soil quality data indicate that the source of the groundwater contamination (described in Section 2.1.3.3) has not been found.

2.1.3.2 Surface Water and Sediment Contamination

During the SI, surface water and/or sediment samples were collected from five storm drain manholes located adjacent to B301 (Figure 1.3). In addition, one sediment sample was collected from the drainage ditch located west of B301 at the Base boundary. Analytical result summary tables are contained in Appendix A. All reported Appendix IX VOCs were estimated values below reporting limits, except for one detection of acetone at 35 $\mu\text{g/kg}$ at MH1. This detection is potentially indicative of laboratory-derived contamination, as are reported concentrations of MEK and methylene chloride. Toluene was detected in two storm drain water samples (MH3 and

MH4) at 1.7J and 1.6J $\mu\text{g/L}$, respectively. Other VOCs detected in the water samples included bromodichloromethane, chloroform, and dibromochloromethane at concentrations ranging from 4.7J $\mu\text{g/L}$ to 13 $\mu\text{g/L}$ (WCC, 1993).

Three RI surface water samples, SW1 through SW3, were collected in surface drainages west of B301 in September 1995 and analyzed for VOCs using USEPA Method SW8021A. Three additional surface water samples (SW4 through SW6) and three sediment samples (SD2 through SD4) were collected in March 1996 and analyzed for Appendix IX VOCs using USEPA Method SW8240 (WCC, 1996). Analytical results for TCE and 1,2-DCE, which were the only two analytes detected, are shown on Plates 2 and 3, respectively. TCE was detected in four surface water samples (SW2, SW4, SW5, and SW6) at concentrations ranging from 1.8 to 17 $\mu\text{g/L}$. All of the detections occurred within the boundaries of the TCE groundwater plume, suggesting that contaminated groundwater is discharging to surface water in this area. The only detection of 1,2-DCE in surface water occurred at station SW6 (3.5 $\mu\text{g/L}$). The only sediment sample containing detectable concentrations of TCE and 1,2-DCE was SD4, located near the inferred southern boundary of the TCE plume. The TCE and 1,2-DCE concentrations detected in this sample were 8 $\mu\text{g/kg}$ and 1.2 $\mu\text{g/kg}$, respectively (WCC, 1996).

2.1.3.3 Groundwater Contamination

Summary tables containing groundwater analytical data from SI and RI sampling activities are provided in Appendix A. As described in Section 1.2.2.2, previous groundwater sampling results have indicated the presence of an areally extensive CAH plume migrating toward the west from the B301 area. Plates 2 and 3 show the distributions of TCE and 1,2-DCE, respectively, in groundwater at the site, following completion of RI sampling activities in April 1996. A vertical profile of the TCE plume is shown on Plate 4. These compounds were the two most frequently detected VOCs in groundwater during the RI. The majority of the results shown on these figures are for samples collected during the July-December 1995 Geoprobe® sampling event and analyzed in the field using a portable GC. The remainder of the results are

from the August 1995 HydroPunch® and the April 1996 monitoring well sampling events. The 1996 samples were analyzed for Appendix IX VOCs at a laboratory using USEPA Method SW8240. Wells sampled in April 1996 included B301-MW1, -MW2S/2D, -MW6, -MW7S/7I/7D, -MW8I, -MW9S/9I, -MW10S, -MW-11S, -MW12S, -TW1, and -TW2. At locations where multiple groundwater samples were collected at different depths during the July-December 1995 sampling event, the maximum detected concentration is shown on Plates 2 and 3. Duplicates for 13 of the Geoprobe® groundwater samples collected in 1995 also were analyzed for VOCs at a laboratory using USEPA Method SW8021A. The ratios of laboratory results to field GC results for 8 of the 13 samples ranged from about 1.6 to 10; indicating that the field GC results were biased low (Appendix A). This observation is supported by the analytical results for the April 1996 monitoring well samples. Where the laboratory results for the April 1996 sampling conflict with field GC results, the laboratory results were used for contouring.

The highest TCE concentration (25,500 µg/L) was detected at HydroPunch® location HP5, located near the northwestern corner of B301. The TCE plume extends approximately 1,000 feet west of the western Offutt AFB boundary (Plate 2). The data suggest the presence of an area of lower concentrations near the Base boundary that separates the TCE plume into two portions. This is evidenced by the truncation of the 100-µg/L isoconcentration contour east of the Base boundary. A more definite separation is apparent for the 1,2-DCE plume (Plate 3). This apparent separation may not be as pronounced as indicated by the field analytical data, but may be at least partially caused by the tendency for the field GC results to be biased low. Alternatively, the separation may be indicative of pulsed releases from the source area or leakage-related dilution from a storm drain that trends toward the west from B301. As shown on Plate 4, beneath the upland terrace the plume is migrating primarily through the glacial outwash sands and gravels which have the highest hydraulic conductivities. Existing data suggest that the plume does not extend into the relatively low-permeability glacial till underlying the outwash deposits.

Unless inhibited by a low-permeability zone, high concentrations (i.e., approaching saturation) of relatively dense compounds such as TCE could migrate to deeper portions of the saturated zone with distance from the source area. However, at lower concentrations, CAHs dissolve and migrate with groundwater. At the source area, TCE concentrations would be expected to be greatest near the groundwater surface. The relatively low magnitude of dissolved CAH concentrations in the shallow portions of the saturated zone at well MW7 relative to intermediate depths suggests that the plume is sourced to the east of MW7, perhaps beneath B301. However, TCE concentrations detected in Geoprobe® and HydroPunch® groundwater samples collected east of MW7 (GS53, HP4) were lower than at MW7, although they were collected at similar depths.

The distribution of DCE in groundwater relative to TCE can provide an indication of ongoing biodegradation of TCE, because DCE can be produced during the biodegradation process. In particular, the distribution of *cis*-1,2-DCE is most useful, because this isomer is preferentially produced through biodegradation of TCE (Bouwer, 1994). Concentrations of *cis*-1,2-DCE, but not *trans*-1,2-DCE, were quantitated during the field GC screening of Geoprobe® groundwater samples. Duplicate Geoprobe® samples and HydroPunch® samples analyzed at Midwest Laboratory in Omaha were analyzed for both *cis*- and *trans*-DCE isomers. Only total 1,2-DCE was reported for monitoring well samples collected in April 1996.

Available data indicate that *cis*-1,2-DCE is more prevalent in groundwater than the *trans* isomer, supporting the interpretation that it is a degradation product of TCE. For example, the HydroPunch® groundwater sample collected at location HP-4 at a depth of 66 feet contained TCE at 725 µg/L, *cis*-1,2-DCE at 50 µg/L, and *trans*-1,2-DCE was not detected. The only detection of vinyl chloride (VC), which is a degradation product of DCE, occurred in Geoprobe® sample GS74 at a concentration of 2 µg/L. As shown on Plate 3, the highest 1,2-DCE concentration (1,500 µg/L) was detected in well MW7I, which, along with adjacent HP5, also contained the highest TCE concentration (Plates 2 and 4). The data indicate the presence of two separate plumes

separated by an area in which 1,2-DCE was largely not detected. This plume configuration supports the premise that releases of CAH to the groundwater have been pulsed. The data also suggest the presence of a second, relatively minor DCE source near the southwestern end of Building 305.

2.1.3.4 Groundwater Geochemistry

During SI sampling activities, groundwater was field screened for electrical conductivity, temperature, pH, and turbidity. Analytical results for these parameters are listed in Table 2.8, and are within normal limits for water table aquifers in the region (WCC, 1993). Conductivity, temperature, turbidity, pH, and dissolved oxygen (DO) data collected during RI well development activities are shown in Table 2.9. Groundwater temperatures beneath the upland terrace and terrace slope were generally higher than temperatures measured beneath the adjacent alluvial valley. The lowest groundwater temperatures [6.4 to 6.6 degrees centigrade (°C)] were measured at well MW9S at the Base boundary. This well is near the north-flowing drainage ditch, and the measured temperature may reflect surface water influence. RI data indicate that the groundwater system is very aerobic, with measured DO concentrations ranging from 7.4 to 14.7 milligrams per liter (mg/L). The solubility of oxygen increases as water temperature decreases, and the oxygen solubility for water at 8 °C is approximately 11 mg/L (American Water Works Association, 1995). Therefore, the measured levels are at or near the oxygen solubility limits, and some of the DO measurements may be erroneously high.

The SI data indicated that groundwater at the B301 study area was of the same general type (calcium-magnesium-bicarbonate) as basewide groundwater, with the exception of samples for wells MW2 and MW6. Groundwater from these two wells had anomalously high chloride contents, and MW2 appeared to have an anomalously high sodium content. Well MW2 is located downgradient from a potential source area for inorganic contaminants. The reason for the high chloride content of groundwater at

TABLE 2.8
SUMMARY OF SI WATER
QUALITY PARAMETERS¹

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Well Number	Date	Electrical Conductivity (μ mhos/cm)	Temperature (°C)	pH	Turbidity (NTU's)
B301-MW1	11-18-91	500	14.7	6.89	21
B301-MW2	11-19-91	600	15.8	6.91	35
B301-MW2D	11-18-91	500	16.6	7.15	46
B301-MW3	11-19-91	530	16.1	7.42	55
B301-MW4	11-18-91	620	14.4	7.07	92
B301-MW5	11-18-91	500	14.9	7.43	86
B301-MW6	11-18-91	610	15.6	7.56	85

¹ Value represents the final water quality sample collected during the purge phase of groundwater sampling

TABLE 2.9
SUMMARY OF RI
MONITORING WELL DEVELOPMENT

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Well Location	Date(s)	Amount Pumped (gallons)	Water Quality Parameters				
			Temperature (°C)	Conductivity (µmhos/cm)	Turbidity (NTUs)	pH	DO (mg/L)
B301-MW9S	3/26/96	20	6.5	0.715	999	6.66	12.2
		80	6.4	0.655	80	7.29	10.7
		140	6.4	0.664	12	7.29	11.1
		200	6.6	0.652	18	7.24	12
B301-MW9I	3/26-27/1996	20	12.1	1.16	999	7.39	11.4
		100	11.9	1.21	259	7.43	8.6
		200	11.8	1.19	67	7.45	8.1
		300	13.2	1.14	50	7.32	12
		400	13.3	1.15	3	7.29	12.8
B301-MW10S	3/22/96	20	8.5	0.731	999	7.36	14.7
		80	8	0.72	17	7.21	13.5
		140	7.8	0.723	137	7.18	14
		200	8.5	0.717	1	7.17	13.4
B301-MW11S	3/21/96	20	9.4	0.696	999	7.03	NA
		80	8.2	0.72	160	7.12	NA
		140	8.5	0.696	101	7.07	NA
		200	8.4	0.697	10	7.11	NA
B301-MW12S	3/21/96	20	10.4	0.821	983	6.7	NA
		80	10.6	0.756	356	7.42	NA
		160	11.7	0.712	14	7.09	NA
		200	11.4	0.714	9	7.08	NA

Source: WCC, 1996.

**TABLE 2.9 (Cont.)
SUMMARY OF RI
MONITORING WELL DEVELOPMENT**

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Well Location	Date(s)	Amount Pumped (gallons)	Water Quality Parameters			
			Temperature (°C)	Conductivity (µmhos/cm)	Turbidity (NTUs)	pH DO (mg/L)
B301-TW1	3/22/96	20	11.1	0.721	843	7.15 13
		80	10.2	0.717	68	7.13 12.5
		140	9.9	0.719	54	7.11 12
		200	9.9	0.719	10	7.12 11.9
B301-TW2	3/22/96	20	8.5	1.07	999	7.34 11.6
		80	8.8	1.06	139	7.37 12.4
		140	8.6	0.993	42	7.36 12.2
		200	8.6	0.989	7	7.37 13.1
B301-MW7S	3/28/96	11	13.6	1.12	999	7.29 8.9
		17	13.6	1.12	657	7.39 8.6
		23	13.8	1.2	244	7.28 9.3
		29	13.9	1.14	28	7.2 13.9
B301-MW7I	3/28/96	45	14.9	0.606	102	12.25 8.8
		85	15	0.617	344	9.38 10.4
		125	15.4	0.758	7	8.36 10.4
		165	15.6	0.783	8	8.05 10.7
B301-MW7D	3/28/96	170	12.8	0.729	7	6.99 9.4
		230	13.8	0.615	24	7.63 9
		290	13.8	0.616	3	7.67 8.7
		350	14	0.618	2	7.61 9.2
B301-MW8I	3/27/96	80	14	0.68	11	7.5 7.4
		160	14.3	0.628	7	7.61 8
		240	14.3	0.669	3	7.62 8.6
		300	14.7	0.624	3	7.6 9.1

Source: WCC, 1996.

well MW6 is not clear, because this well is located upgradient from B301. For major ions other than chloride, groundwater from the B301 area also generally falls within the background range (WCC, 1993).

2.1.4 Soil Total Organic Carbon Content

Four soil samples were analyzed for total organic carbon (TOC) during the RI (Appendix A). TOC concentrations ranged from not detected (less than 0.20 percent) at the base of the loess deposits in the borehole for well MW7I, to 0.76 percent in shallow alluvial sediments. All of the TOC detections occurred in samples collected from the alluvial sediments west of the Base boundary.

2.2 DEVELOPMENT OF CONCEPTUAL MODELS

A conceptual model is a three-dimensional representation of a hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. A site-specific conceptual model is developed to provide an understanding of the mechanisms controlling contaminant fate and transport and to identify additional data requirements. The model describes known and suspected sources of contamination, types of contamination, affected media, and contaminant migration pathways. The model also provides a foundation for formulating decisions regarding additional data collection and potential remedial actions. The conceptual model for B301 will be used to aid in selecting additional data collection points and to identify appropriate data needs for modeling chlorinated solvent attenuation using groundwater flow and solute transport models.

Successful conceptual model development involves:

- Defining the problem to be solved;
- Integrating available data, including
 - Local geologic and topographic data,

- Hydraulic data,
- Site stratigraphic data, and
- Contaminant concentration and distribution data;
- Evaluating contaminant fate and transport characteristics;
- Identifying contaminant migration pathways;
- Identifying potential receptors and exposure points; and
- Determining additional data requirements.

2.2.1 RNA and Solute Transport Models

After a site has been adequately characterized, fate and transport analyses can be performed to determine the potential for contaminant migration and human and ecological receptor pathway completion. Groundwater flow and solute transport models have proven useful for predicting plume migration and contaminant attenuation by natural biodegradation. Analytical and numerical models are available for modeling the fate and transport of CAHs under the influence of advection, dispersion, sorption, and natural aerobic and anaerobic biodegradation. Analytical models derived from advection-dispersion equations [e.g., models such as those presented by Wexler (1992) and van Gneuchten and Alves (1982)] may be useful. However, because CAH biodegradation may be the result of different processes in different locations, it may be necessary to use a numerical model to incorporate spatial variability in contaminant decay rates.

An accurate estimate of the potential for natural biodegradation of chlorinated compounds in groundwater is important to consider when determining whether groundwater contamination presents a substantial threat to human health and the environment, and when deciding what type of remedial alternative will be most cost effective in eliminating or abating these threats. Over the past two decades, numerous

laboratory and field studies have demonstrated that subsurface microorganisms can degrade a variety of hydrocarbons and chlorinated solvents (Lee, 1988; McCarty *et al.*, 1992). The following section discusses the biodegradation of CAHs.

2.2.2 Biodegradation of CAHs

Chlorinated solvents can be transformed, directly or indirectly, by biological processes (e.g., Bouwer *et al.*, 1981; Wilson and Wilson, 1985; Miller and Guengerich, 1982; Nelson *et al.*, 1986; Bouwer and Wright, 1988; Little *et al.*, 1988; Mayer *et al.*, 1988; Arciero *et al.*, 1989; Cline and Delfino, 1989; Freedman and Gosset, 1989; Folsom *et al.*, 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; DeStefano *et al.*, 1991; Henry, 1991; McCarty *et al.*, 1992; Hartmans and de Bont, 1992; McCarty and Semprini, 1994; Vogel, 1994). CAHs may undergo biodegradation through three different pathways: use as an electron acceptor, use as an electron donor, or cometabolism, which is degradation resulting from exposure to a catalytic enzyme fortuitously produced during an unrelated process. At a given site, one or all of these processes may be operating, although at many sites the use of CAHs as electron acceptors appears to be the most important.

In a pristine aquifer, native organic carbon is utilized as an electron donor and DO is utilized first as the prime electron acceptor. Where anthropogenic carbon (e.g., fuel hydrocarbons or low-molecular-weight CAHs) is present, it also will be utilized as an electron donor. After the DO is consumed, anaerobic microorganisms typically use native electron acceptors (as available) in the following order of preference: nitrate, ferric iron oxyhydroxide, sulfate, and finally carbon dioxide. Evaluation of the distribution of these electron acceptors can provide evidence of where and how CAH biodegradation is occurring. In addition, because CAHs may be used as electron acceptors or electron donors (in competition with other acceptors or donors), maps showing the distribution of these compounds will also provide evidence on the types of biodegradation processes acting at a site.

As with benzene, toluene, ethylbenzene, and xylenes (BTEX), the driving force behind reduction/oxidation (redox) reactions resulting in CAH degradation is electron transfer. Although thermodynamically favorable, most of the reactions involved in CAH reduction and oxidation cannot proceed abiotically because of the lack of activation energy. Microorganisms are capable of providing the necessary activation energy; however, they will facilitate only those redox reactions that have a net yield of energy. A more complete description of the main types of biodegradation reactions affecting CAHs is presented in the following subsections.

2.2.2.1 Electron Acceptor Reactions (Reductive Dehalogenation)

Under anaerobic conditions, biodegradation of chlorinated solvents usually proceeds through a process called reductive dehalogenation. During this process, the halogenated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a halogen atom is removed and replaced with a hydrogen atom. Figure 2.6 illustrates the transformation of chlorinated ethenes via reductive dehalogenation. In general, reductive dehalogenation occurs by sequential dechlorination from PCE to TCE to DCE to vinyl chloride (VC) to ethene. Depending upon environmental conditions, this sequence may be interrupted, with other processes then acting upon the products. During reductive dehalogenation, all three isomers of DCE can theoretically be produced; however, Bouwer (1994) reports that under the influence of biodegradation, *cis*-1,2-DCE is a more common intermediate than *trans*-1,2-DCE and that 1,1-DCE is the least prevalent intermediate of the three DCE isomers. Reductive dehalogenation of chlorinated solvent compounds is associated with the accumulation of daughter products and an increase in chloride.

Reductive dehalogenation affects each of the chlorinated ethenes differently. PCE is the most susceptible of these compounds to reductive dehalogenation because it is the most oxidized. Conversely, VC is the least susceptible to reductive dehalogenation because it is the least oxidized of these compounds. The rate of reductive dehalogenation also has been observed to decrease as the degree of chlorination

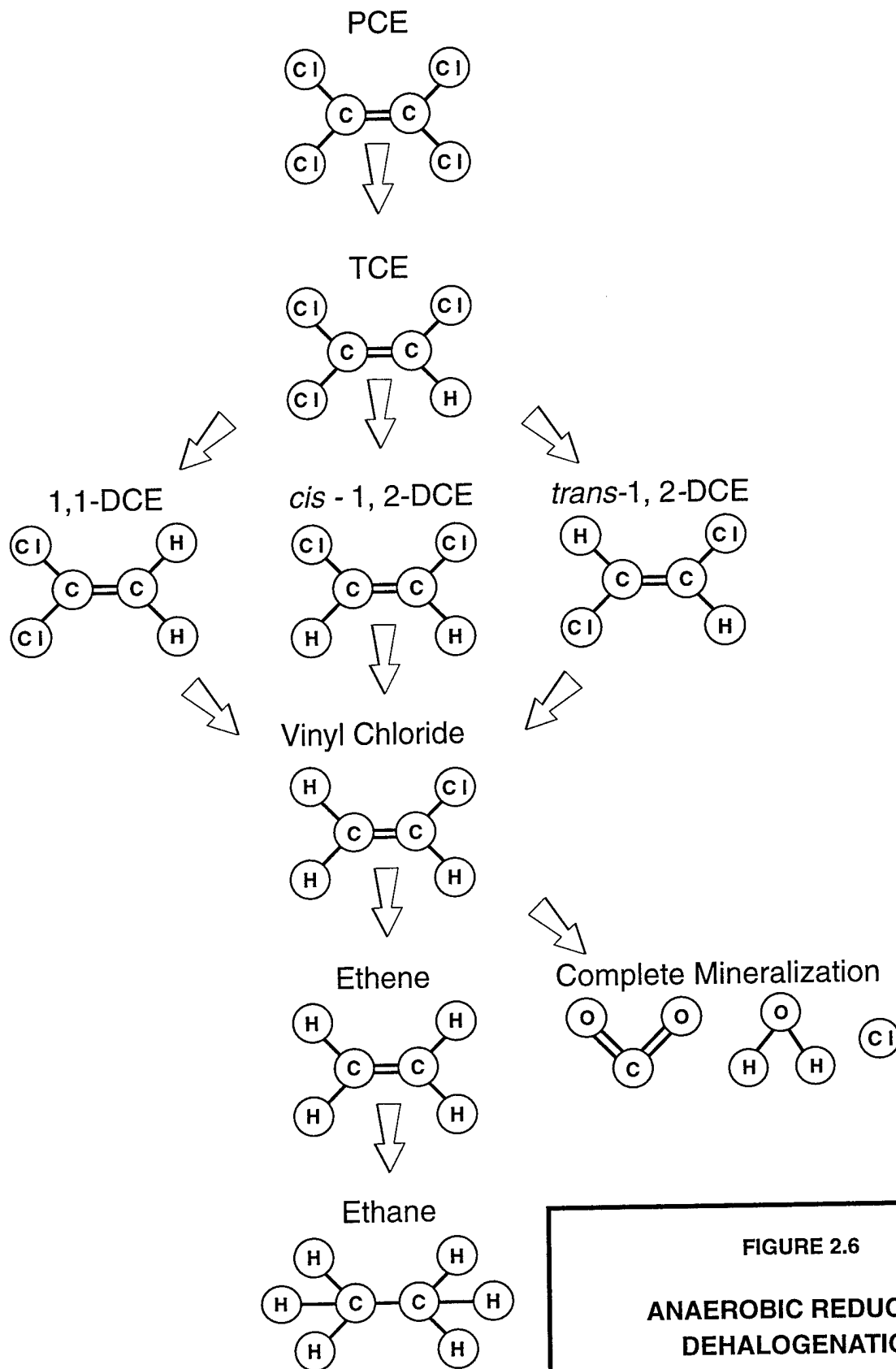


FIGURE 2.6

**ANAEROBIC REDUCTIVE
DEHALOGENATION**

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

**PARSONS
ENGINEERING SCIENCE, INC.**

decreases (Vogel and McCarty, 1985; Bouwer, 1994). Murray and Richardson (1993) have postulated that this rate decrease may explain the accumulation of VC in PCE and TCE plumes that are undergoing reductive dechlorination. Reductive dehalogenation has been demonstrated under nitrate- and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of CAHs, occur under methanogenic conditions (Bouwer, 1994).

Because CAH compounds are used as electron acceptors, there must be an appropriate source of carbon for microbial growth in order for reductive dehalogenation to occur (Bouwer, 1994). Potential carbon sources can include low-molecular-weight compounds (e.g., lactate, acetate, methanol, or glucose) present in natural organic matter, or fuel hydrocarbons.

2.2.2.2 Electron Donor Reactions

Under aerobic conditions some CAH compounds can be utilized as the primary substrate (i.e., electron donor) in biologically mediated redox reactions (McCarty and Semprini, 1994). In this type of reaction, the facilitating microorganism obtains energy and organic carbon from the degraded CAH. In contrast to reactions in which the CAH is used as an electron acceptor, only the least oxidized CAHs can be utilized as electron donors in biologically mediated redox reactions. McCarty and Semprini (1994) describe investigations in which VC and 1,2-DCA were shown to serve as primary substrates. These authors also document that dichloromethane has the potential to function as a primary substrate under either aerobic or anaerobic environments. In addition, Bradley and Chapelle (1996) show evidence of mineralization of VC under iron-reducing conditions so long as there is sufficient bioavailable ferric iron (III). Murray and Richardson (1993) write that microorganisms are generally believed to be incapable of growth using TCE and PCE. Aerobic metabolism of VC may be characterized by a loss of VC mass, a decreasing molar ratio of VC to other CAH compounds, and the presence of chloromethane.

2.2.2.3 Cometabolism

When a CAH is biodegraded through cometabolism, it serves as neither an electron acceptor nor a primary substrate in a biologically mediated redox reaction. Instead, the degradation of the CAH is catalyzed by an enzyme or cofactor that is fortuitously produced by organisms for other purposes. The organism receives no known benefit from the degradation of the CAH; rather the cometabolic degradation of the CAH may in fact be harmful to the microorganism responsible for the production of the enzyme or cofactor (McCarty and Semprini, 1994).

Cometabolism is best documented in aerobic environments, although it potentially could occur under anaerobic conditions. Aerobic biodegradation pathways for chlorinated ethenes are illustrated in Figure 2.7. It has been reported that under aerobic conditions, chlorinated ethenes, with the exception of PCE, are susceptible to cometabolic degradation (Murray and Richardson, 1993; Vogel, 1994; McCarty and Semprini, 1994). Vogel (1994) further elaborates that the cometabolism rate increases as the degree of dechlorination decreases.

In the cometabolic process, TCE is indirectly transformed by bacteria as BTEX or another substrate is used to meet their energy requirements. Therefore, TCE does not enhance the degradation of BTEX or other carbon sources, nor will its cometabolism interfere with the use of electron acceptors involved in the oxidation of those carbon sources. It is likely that depletion of suitable substrates (BTEX or other organic carbon sources) may limit cometabolism of CAHs.

2.2.2.4 Behavior of Chlorinated Solvent Plumes

Chlorinated solvent plumes can exhibit three types of behavior depending on the amount of solvent, the amount of organic (native and/or anthropogenic) carbon in the aquifer, the distribution and concentration of natural electron acceptors, and the types of electron acceptors being utilized. Individual plumes may exhibit all three types of behavior in different portions of the plume. The different types of plume behavior are summarized below.

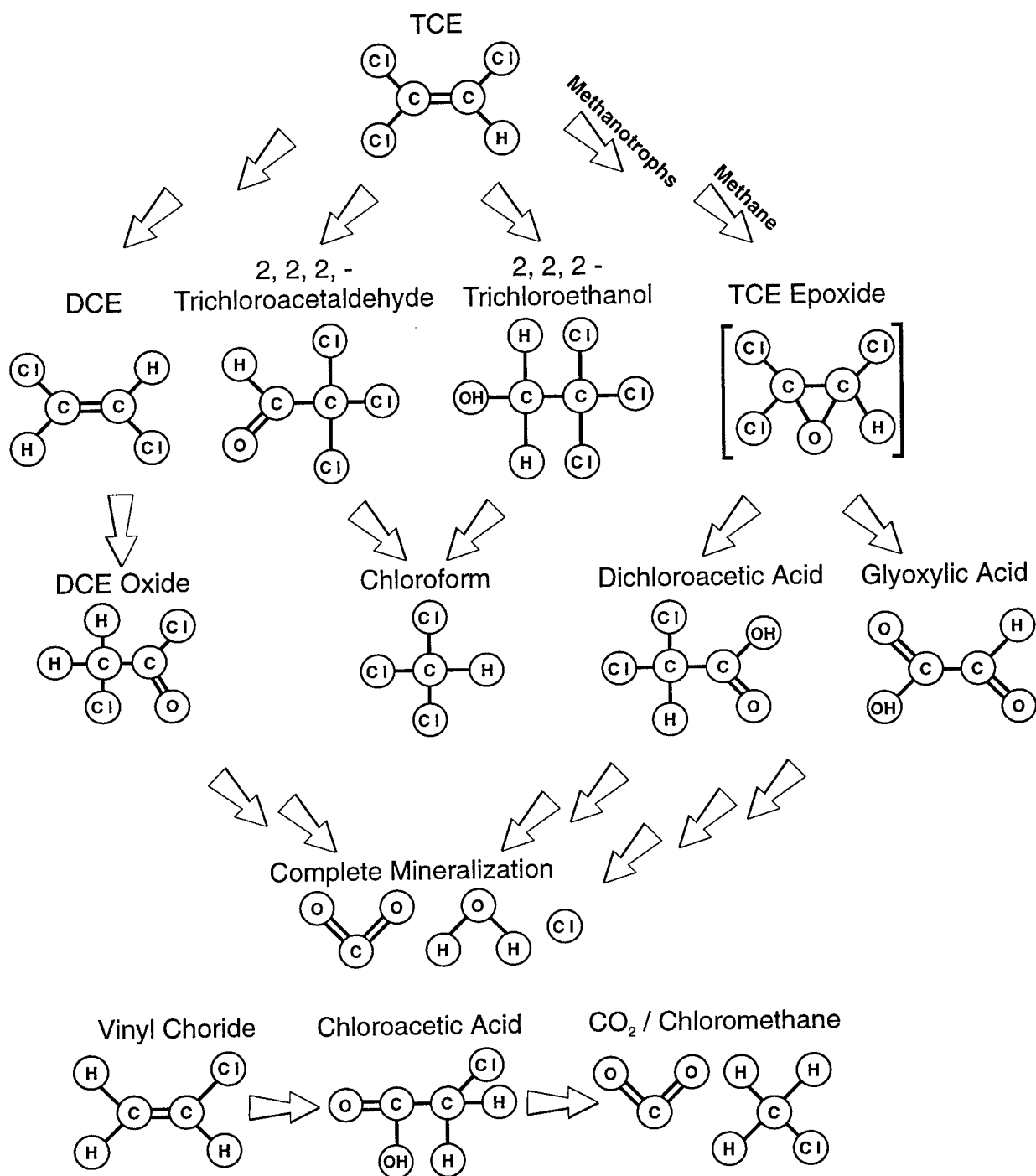


FIGURE 2.7

AEROBIC DEHALOGENATION

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

**PARSONS
ENGINEERING SCIENCE, INC.**

2.2.2.4.1 Type 1 Behavior

Type 1 behavior occurs where the primary substrate is anthropogenic carbon (e.g., BTEX or landfill leachate) and this anthropogenic carbon drives reductive dechlorination. When evaluating intrinsic remediation of a plume exhibiting type 1 behavior the following questions must be answered:

- 1) Does electron acceptor supply exceed demand (i.e., is the electron acceptor supply adequate)?
- 2) Will the CAH plume strangle before it starves [i.e., will it run out of CAHs (electron acceptors) before it runs out of primary substrate (anthropogenic carbon)]?
- 3) What is the role of competing electron acceptors?
- 4) Is VC oxidized or is it reduced?

2.2.2.4.2 Type 2 Behavior

Type 2 behavior dominates in areas that are characterized by relatively high native organic carbon concentrations, and this carbon source drives reductive dechlorination (i.e., the primary substrate for microorganism growth is native organic carbon). When evaluating RNA of a type 2 chlorinated solvent plume, the same questions as those posed in the description of type 1 behavior must be answered.

2.2.2.4.3 Type 3 Behavior

Type 3 behavior dominates in areas that are characterized by low native and/or anthropogenic carbon concentrations, and DO concentrations that are greater than 1.0 mg/L. Under these conditions the plume is aerobic and reductive dehalogenation will not occur. Thus there is no reductive dehalogenation of PCE, TCE, and DCE. Biodegradation may proceed via the much slower process of cometabolism, but will be limited by the low concentrations of native or anthropogenic carbon. The most

significant natural attenuation mechanisms for these compounds will be advection, dispersion, and sorption. However, VC could be oxidized under these conditions.

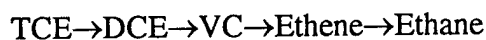
2.2.2.4.4 Mixed Behavior

As mentioned above, a single chlorinated solvent plume can exhibit all three types of behavior in different portions of the plume. This can be beneficial for natural biodegradation of CAH plumes. For example Wiedemeier *et al.* (1996) describe a plume at Plattsburgh AFB, NY that exhibits type 1 behavior in the source area and type 3 behavior downgradient from the source. The best scenario involves a plume in which TCE and DCE are reductively dechlorinated (type 1 or 2 behavior), then VC is oxidized (type 3 behavior), either aerobically or anaerobically (via iron reduction). VC is oxidized to carbon dioxide (CO₂) in this type of plume and does not accumulate. The following sequence of reactions occurs in this type of plume:



In general, the TCE, DCE, and VC go away at approximately the same rate and thus these reactions may be confused with simple dilution. Note that no ethene is produced during this reaction. VC is removed from the system much faster under these conditions than it is under VC-reducing conditions.

A less desirable scenario involves a plume in which all CAHs are reductively dechlorinated (type 2 or 3 behavior). VC is reduced to ethene, which is further reduced to ethane. The following sequence of reactions occur in this type of plume (Figure 2.6):



In this type of plume, DCE and VC degrade more slowly than TCE, and thus they tend to accumulate. This is the type of reductive dechlorination described by Freedman and Gossett (1989).

2.2.3 Initial Conceptual Model

Geologic and hydrogeologic data for the B301 SWMU were previously used to produce a hydrogeologic profile of the site (WCC, 1996). Profile B-B' (Plate 1) shows that the major subsurface units include loess, glacial outwash, glacial till, and alluvial silt and clay. The CAH plume is migrating primarily through the glacial outwash occupying the upland terrace and terrace slopes, and beneath the alluvial silt and clay occupying the Papillion Creek alluvial valley west of the upland terrace. The plume does not appear to penetrate into the relatively low-permeability till which underlies the outwash deposits.

Figure 2.5 is a groundwater surface map prepared using 1996 groundwater elevation data (WCC, 1996). Groundwater is present beneath the upland terrace at approximately 45 to 50 feet bgs. The depth to groundwater decreases to the west beneath the terrace slopes, and is approximately 3 to 10 feet bgs below the Papillion Creek alluvial valley. Groundwater flows generally to the west, with a slight southwesterly trend in the furthest downgradient portion of the plume. On the basis of the available data, Parsons ES will model the site as a heterogeneous, unconfined aquifer consisting of sandy, silty, and clayey zones. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

CAHs, the chemicals of concern in groundwater at B301, will be the primary focus of this RNA demonstration. CAHs are expected to leach from contaminated soil into the groundwater, and to migrate laterally as a dissolved contaminant plume. However, available site data suggest that the contaminated soil source area has not been located.

In addition to the effects of mass transport mechanisms (volatilization, dispersion, diffusion, and adsorption), these dissolved contaminants may be removed from the groundwater system by naturally occurring destructive attenuation mechanisms, such as biodegradation. Given available information, the CAH plume originating at B301 appears to be a type 3 plume, with aerobic conditions dominating throughout the plume. Despite predominantly aerobic conditions, a limited amount of reductive

dehalogenation from TCE to 1,2-DCE (primarily the *cis* isomer) may be occurring, but the scarcity of other degradation products such as VC indicates that reductive dehalogenation is not proceeding further. At the head of the plume at well MW7I, the ratio of 1,2-DCE to TCE is 0.06. Near the downgradient toe of the plume at well MW11 the magnitude of this ratio is 8.9, indicating that the concentration of biodegradation daughter products is increasing relative to the parent TCE with distance from the source area. The change in this ratio suggests an accumulation of *cis*-1,2-DCE in the aquifer with respect to TCE. An alternative explanation for the presence of 1,2-DCE in groundwater is that this compound was a contaminant in the TCE used at B301. This would explain why the location of the highest 1,2-DCE concentration coincides with the location of the highest TCE concentration.

The effects of these fate and transport processes on the dissolved CAH groundwater plume will be investigated using quantitative groundwater analytical data and the solute-transport models. Data collection and analysis requirements are discussed in Section 3 of this work plan.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the demonstration and to assess the degree to which RNA of chlorinated solvents is occurring at B301, additional site-specific chemical and hydrogeologic data will be collected to supplement the available site data. Many of these measurements and analyses are commonly performed at hazardous waste sites; however, some of the chemical and hydrogeologic data will be collected specifically to assess the potential for use of RNA for the CAH plume originating from B301. Physical hydrogeologic parameters will be measured to further refine the site conceptual model and to aid in assembling and calibrating the groundwater flow portion of a site-specific transport model.

Physical hydrogeologic characteristics to be determined include:

- Depth from measurement datum to the groundwater surface in site monitoring wells and points;
- Surface water flow rate measurements;
- Locations of potential groundwater recharge and discharge areas;
- Locations of off-Base downgradient wells and their uses;
- Hydraulic conductivity through slug tests;
- Stratigraphic analysis of subsurface media; and
- Groundwater temperature.

Chemical hydrogeologic characteristics to be determined include:

- DO concentration;
- Specific conductance;
- pH;
- Oxidation/reduction potential (ORP);
- TOC content of saturated soils; and
- Additional chemical analysis of groundwater, surface water, soil, and sediment for the parameters listed in Table 3.1.

In general, analyses will be made to allow an inference of what biodegradation processes are ongoing, as well as to provide information useful for solute transport modeling. Some inorganic groundwater chemical parameters [e.g., ferrous iron, DO, or sulfate] are measured to evaluate if there is any ongoing degradation of native (or anthropogenic) carbon. If such processes are ongoing, it may facilitate degradation of CAHs via the pathways discussed in Section 2.2.2. Chloride data can be used as an indicator of dechlorination, which would increase chloride concentrations in the plume interior. Carbon dioxide data may also indicate degradation, as it is the ultimate product of many of the reaction pathways indicated on Figures 2.6 and 2.7. ORPs will be measured to help evaluate whether conditions are reducing enough for reductive dehalogenation, and as an indicator parameter for well purging (along with DO, temperature, pH, and conductivity). Methane, ethane, and ethene will be measured for evidence of complete dehalogenation of CAHs, while VOC concentrations can also be used to further evaluate the ongoing processes, as discussed in Section 2.2.2. Soil analyses will be performed primarily to gain information on the distribution and concentrations of organic carbon, which can aid in sorption or act as an electron donor. However, selected soil samples will also be analyzed for VOCs if field headspace measurements indicate that significant concentrations of VOCs are present. Additional

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUNDWATER, SURFACE WATER, SOIL, AND SEDIMENT SAMPLES
BUILDING 301
INTRINSIC REMEDIATION TS
OFFUTT AFB, NEBRASKA

MATRIX Analyte	METHOD	FIELD (F) OR FIXED-BASE LABORATORY (L)
GROUNDWATER		
Total Iron	Colorimetric, Hach Method 8008	F
Ferrous Iron (Fe ²⁺)	Colorimetric, Hach Method 8146	F
Ferric Iron (Fe ³⁺)	Difference between total and ferrous iron	F
Manganese	Colorimetric, Hach Method 8034	F
Sulfate	Colorimetric, Hach Method 8051	F
Nitrate	Titrimetric, Hach Method 8039	F
Nitrite	Titrimetric, Hach Method 8507	F
Redox Potential	A2580B, direct-reading meter	F
Oxygen	Direct-reading meter	F
pH	E150.1/SW9040, direct-reading meter	F
Conductivity	E120.1/SW9050, direct-reading meter	F
Temperature	E170.1, direct-reading meter	F
Carbon Dioxide	Titrimetric, Hach Method 1436-01	F
Alkalinity (Carbonate [CO ₃ ²⁻] and Bicarbonate [HCO ₃ ⁻])	F = Titrimetric, Hach Method 8221 L = USEPA M+B54ethod 310.1	F L
Nitrate + Nitrite	USEPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane, Ethene	RSKSOP-147 ^{a/}	L
Dissolved Organic Carbon	RSKSOP-102	L
VOCs (CAHs)	RSKSOP-148	L
Fuel Carbon	RSKSOP-148	L
SURFACE WATER		
VOCs	RSKSOP-148	L
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
VOCs	RSKSOP-124, modified	L
SEDIMENT		
VOCs	RSKSOP-124, modified	L
Total Organic Carbon	RSKSOP-102 and RSKSOP-120	L

^{a/} RSKSOP = Robert S. Kerr Laboratory(now NRMRL) Standard Operating Procedure.

NOTE: Additional analyses (as indicated in Appendix A) may also be performed at the discretion of Parsons ES and USEPA NRMRL personnel.

analyses not listed in Table 3.1 may be performed at the discretion of the USEPA NRMRL scientists working at this site. Additional analytes that may be tested for are listed in Appendix B.

To obtain these data, soil, groundwater, surface water, and sediment samples will be collected and analyzed. Because the previous RI was unable to locate a CAH contamination source in the vadose zone, suggesting that it is located beneath B301, additional soil quality samples will not be collected for VOC analysis during this field program, unless field headspace screening indicates that VOCs are present. The following sections describe the procedures that will be followed when collecting additional site-specific data. To the extent possible, a Geoprobe® will be used to perform subsurface investigations, including borehole advancement, soil sampling, and installation of small-diameter groundwater monitoring points. However, the greater depth to groundwater beneath the upland terrace at B301 will preclude use of the Geoprobe® in this area because a peristaltic pump, used to purge and sample the small-diameter monitoring points, cannot be used if the depth to groundwater exceeds approximately 20 feet. Therefore, larger-diameter conventional groundwater monitoring wells will be installed using a truck-mounted drilling rig at upland terrace locations where groundwater monitoring is desired. Field preparation procedures are described in Section 3.1. Procedures to be used for the drilling and installation of new monitoring points and wells are described in Section 3.2. Procedures to be used to sample groundwater monitoring wells/points, and surface water are described in Section 3.3. Surface water and sediment sampling procedures and sample handling procedures are described in Sections 3.4 and 3.5, respectively. Procedures used to measure surface water flow rates and aquifer parameters (e.g., hydraulic conductivity) are described in Sections 3.6 and 3.7, respectively.

3.1 UTILITY CLEARANCE, DIGGING PERMITS, AND WATER SOURCE VERIFICATION

Base personnel will be responsible for identifying the locations of all utility lines, fuel lines, or any other underground infrastructure prior to any intrusive sampling

activities. All necessary digging permits will be obtained through Base personnel prior to mobilizing to the field or during the course of the field activities. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed locations.

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the Base potable water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2 MONITORING POINT/MONITORING WELL DRILLING, SOIL SAMPLING, AND INSTALLATION

To further characterize site hydrogeologic conditions and groundwater chemistry, an estimated total of up to 18 additional groundwater monitoring points and wells will be installed within and adjacent to the B301 CAH plume to supplement previously installed site monitoring wells. Small-diameter monitoring points will be installed using a Geoprobe® in areas where the groundwater surface is sufficiently near the ground surface (within approximately 20 feet) to allow use of a peristaltic pump to perform purging and sampling activities. Two-inch inside-diameter (ID) monitoring wells will be installed in areas where the depth to groundwater is deeper than approximately 20 feet. The following sections describe the proposed monitoring point and well locations and completion intervals, monitoring point installation, monitoring point development, and equipment decontamination procedures. If site conditions prevent installation of monitoring points, groundwater grab samples will be collected using the Geoprobe® apparatus.

3.2.1 Monitoring Point and Well Locations and Completion Intervals

The locations of the proposed 9 additional groundwater monitoring points and 10 additional groundwater monitoring wells, including 1 optional well, are identified on Figure 3.1. These locations were determined following a review of data gathered during previous site activities (WCC, 1993 and 1996). Monitoring point and well

locations were selected to provide hydrogeologic data necessary for successful implementation of a site-specific contaminant fate and transport model and to monitor potential chlorinated solvent migration from the site. Monitoring point/well locations were also selected to provide additional data on natural attenuation processes in the CAH plume. The 19 proposed locations shown on Figure 3.1 may be modified in the field as a result of conditions encountered in the field and acquired field data. The points/wells will be placed with the intent of verifying the downgradient plume extent and for collecting additional data from within, up-, and cross-gradient from the plume. The rationale for the location of each of the proposed monitoring points/wells is provided in Table 3.2. Installation of one of the wells, MW20, will be optional as described in Table 3.2.

Monitoring points/wells may be installed singly, or in clusters of up to three points or wells. Single monitoring points will be screened in the proper interval to detect maximum contaminant concentrations on the basis of RI data provided by WCC (1996). Estimated midpoints of screen intervals for all of the proposed monitoring wells and points are indicated in Table 3.2. These intervals may be altered in the field based on actual conditions encountered. Monitoring point clusters will be installed at locations where it is desirable to assess variations in groundwater chemistry with depth in the saturated zone.

3.2.2 Monitoring Point and Well Advancement and Installation Procedures

3.2.2.1 Monitoring Point Advancement, Soil Sampling, and Installation Procedures

Advancement of monitoring point boreholes will be accomplished using a Geoprobe® system, which is a hydraulically powered percussion/probing machine capable of advancing sampling tools through unconsolidated soils. This system allows rapid collection of soil, soil gas, or groundwater samples at shallow depths while minimizing the generation of investigation-derived waste materials. Figure 3.2 is a diagram of the Geoprobe® system.

TABLE 3.2
SUMMARY OF PROPOSED MONITORING WELLS/POINTS
BUILDING 301
INTRINSIC REMEDIATION TS
OFFUTT AFB, NEBRASKA

Well/Point Identification ^{a/}	Screened Interval (ft bgs) ^{b/}	Rationale
B301-MP1(S)	17	Confirm apparent division of plume into two sub-plumes. A groundwater grab sample will also be collected from a depth of 50 feet to ensure that the plume is not "diving" below the alluvial deposits in the tongue of glacial outwash (see Plate 4).
B301-MP2(S)	20	Bound plume on north side at Base boundary and collect cross-gradient geochemical data.
B301-MP3(S)	20	Bound plume on south side at Base boundary and collect cross-gradient geochemical data.
B301-MP4(I)	30	Determine vertical extent of plume along apparent plume axis.
B301-MP5(S)	15	Bound plume on north side in off-Base area.
B301-MP6(S)	15	Determine extent of contamination detected at well B301-MW10.
B301-MP7(S)	15	Confirm estimated western extent of plume.
B301-MP8(S)	15	Confirm estimated western extent of plume.
B301-MP9(S)	15	Confirm estimated southern extent of plume in off-Base area.
B301-MW13(I)	67	Assess whether contaminant concentrations in the intermediate saturated zone upgradient of B301-MW7I increase or decrease to evaluate B301 as a possible source area.
B301-MW14(I)	67	Monitor groundwater quality adjacent to elevated TCE detection in GS63.
B301-MW15(I)	60	Pair B301-MW1 with intermediate-depth well to assess southern plume boundary at this depth and collect cross-gradient geochemical data.
B301-MW16(I)	60	Install additional intermediate-depth well along plume axis to monitor chemical changes with distance from source area.
B301-MW17(I)	60	Assess northern plume boundary at intermediate depth and collect cross-gradient geochemical data.
B301-MW8S/8D	25 (shallow) 52 (deep)	Install shallow and deep wells adjacent to MW8I to provide vertical chemical profile along plume axis.
B301-MW18(I)	65	Assess upgradient groundwater conditions at an intermediate depth.
B301-MW19(I)	67	Assess northern extent of the plume at an intermediate depth in source area and provide additional background data.
B301-MW-20(I) (optional)	65	Assess groundwater quality downgradient of B301-MW14, if substantial contamination is detected in MW14.

a/ MP = monitoring point installed with a Geoprobe®; MW = monitoring well installed with a truck-mounted drilling rig.

b/ Depths indicate the approximate midpoint of the screened interval. Depths may vary depending on field conditions encountered.

(S) = shallow.

(I) = intermediate.

(D) = deep.

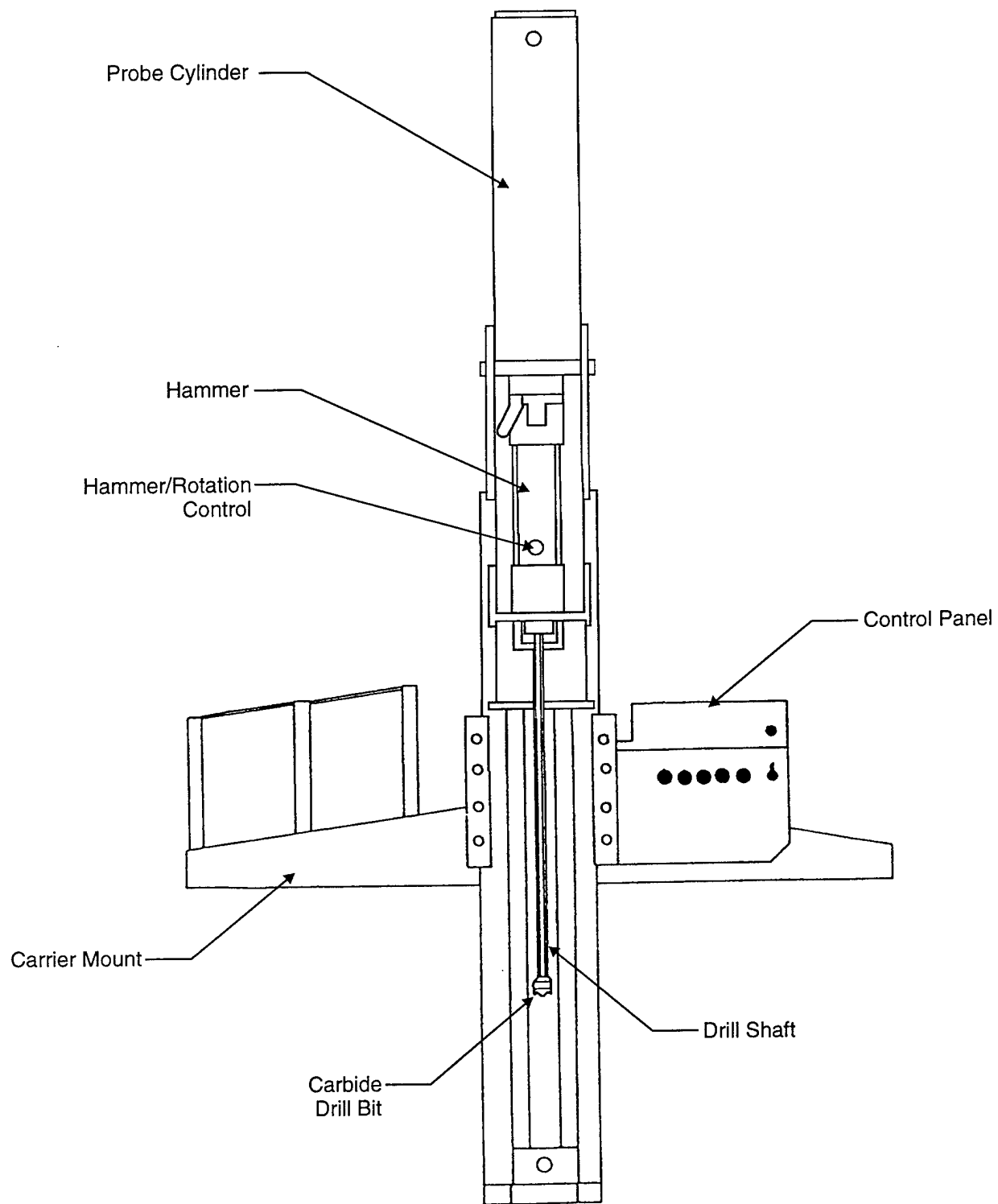


FIGURE 3.2

**CROSS-SECTION
OF GEOPROBE®**

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

**PARSONS
ENGINEERING SCIENCE, INC.**

Using this technique, a probe-drive sampler that serves as both the driving point and the soil sample collection device is attached to the leading end of the probe rods. To advance the borehole and collect a soil sample, the sampler is pushed or driven to the desired sampling depth, and the stop pin is removed, allowing the piston and drive point to retract as the sample barrel is pushed into undisturbed soil. If desired, a brass, stainless steel, or clear acetate liner can be inserted into the sampling barrel to hold the soil cores. The probe rods are then retracted, bringing the sampling device and core sample to the surface. The soil sample can then be extruded from the liners for lithologic logging, or the liners can be cut to the desired length, capped, and submitted to the analytical laboratory for testing of the undisturbed samples. If soil samples are only desired at specific intervals rather than continuously, the stop pin is not removed, and the probe rods and closed sample barrel are pushed to the desired sampling depth. If the probe-drive sampling technique described above is inappropriate, inadequate, or unable to efficiently provide sufficient soil samples for the characterization of the site, continuous soil samples will be obtained from conventional soil boreholes using a truck-mounted auger drilling rig.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example geologic borehole log form is presented in Figure 3.3. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination (as indicated by photoionization detection (PID) readings);

GEOLOGIC BORING LOG

BORING NO.: _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: _____ RIG TYPE: _____ DATE CMPL.: _____
 JOB NO.: _____ DRLG METHOD: _____ ELEVATION: _____
 LOCATION: _____ BORING DIA.: _____ TEMP: _____
 GEOLOGIST: _____ DRLG FLUID: _____ WEATHER: _____

COMENTS: _____

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	TLY(ppm)	TOTAL BTEX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1										
	5										
	10										
	15										
	20										
	25										
	30										
	35										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB



Water level drilled

FIGURE 3.3

GEOLOGIC BORING LOG

Building 301
 Intrinsic Remediation TS
 Offutt Air Force Base, Nebraska

**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

- Lithologic description, including relative density, color, major textural constituents, minor constituents, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

Monitoring point installation and completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, the well points, casing, and tubing will be cleaned prior to use with a high-pressure, steam/hot-water cleaner using approved water. Materials that cannot be cleaned to the satisfaction of the field scientist will not be used. Where possible, monitoring points will have 0.5-inch ID, 3-foot-long polyvinyl chloride (PVC) factory-slotted screens connected to 0.5-inch ID PVC riser pipe. However, deeper monitoring points may have 6-inch-long, 0.5-inch-diameter, stainless steel screens connected to 0.375-inch Teflon®-lined tubing.

3.2.2.1.1 PVC Monitoring Points

If subsurface conditions permit, monitoring points will be constructed of 0.75-inch outside-diameter (OD)/0.5-inch-ID PVC casing and well screen to provide additional water level information. Approximately 3 feet of factory-slotted screen will be installed for each shallow monitoring point. Effective installation of the shallow monitoring points requires that the boreholes remain temporarily open upon completion of drilling. Shallow 0.5-inch-ID PVC monitoring points will be installed by punching and sampling a borehole with the Geoprobe®. Upon removing the rods, the borehole depth will be measured to determine if the hole remains open. If the borehole is open, the 0.5-inch-ID PVC casing and screen will be placed at the appropriate depths. The annular space around the screen will be filled with sand filter pack, and the annulus around the casing will be filled with grout or bentonite. Monitoring point construction

details will be noted on a Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

Monitoring point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 0.5 inch. The screens will be factory slotted with 0.01-inch openings. Monitoring point screens will be placed to sample and provide water level information at or near the water table. Blank monitoring point casing will be constructed of Schedule 40 PVC with an ID of 0.5 inch. All monitoring point casing sections will be flush-threaded; joints will not be glued. The casing at each monitoring point will be fitted with a bottom cap and a top cap constructed of PVC.

The field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

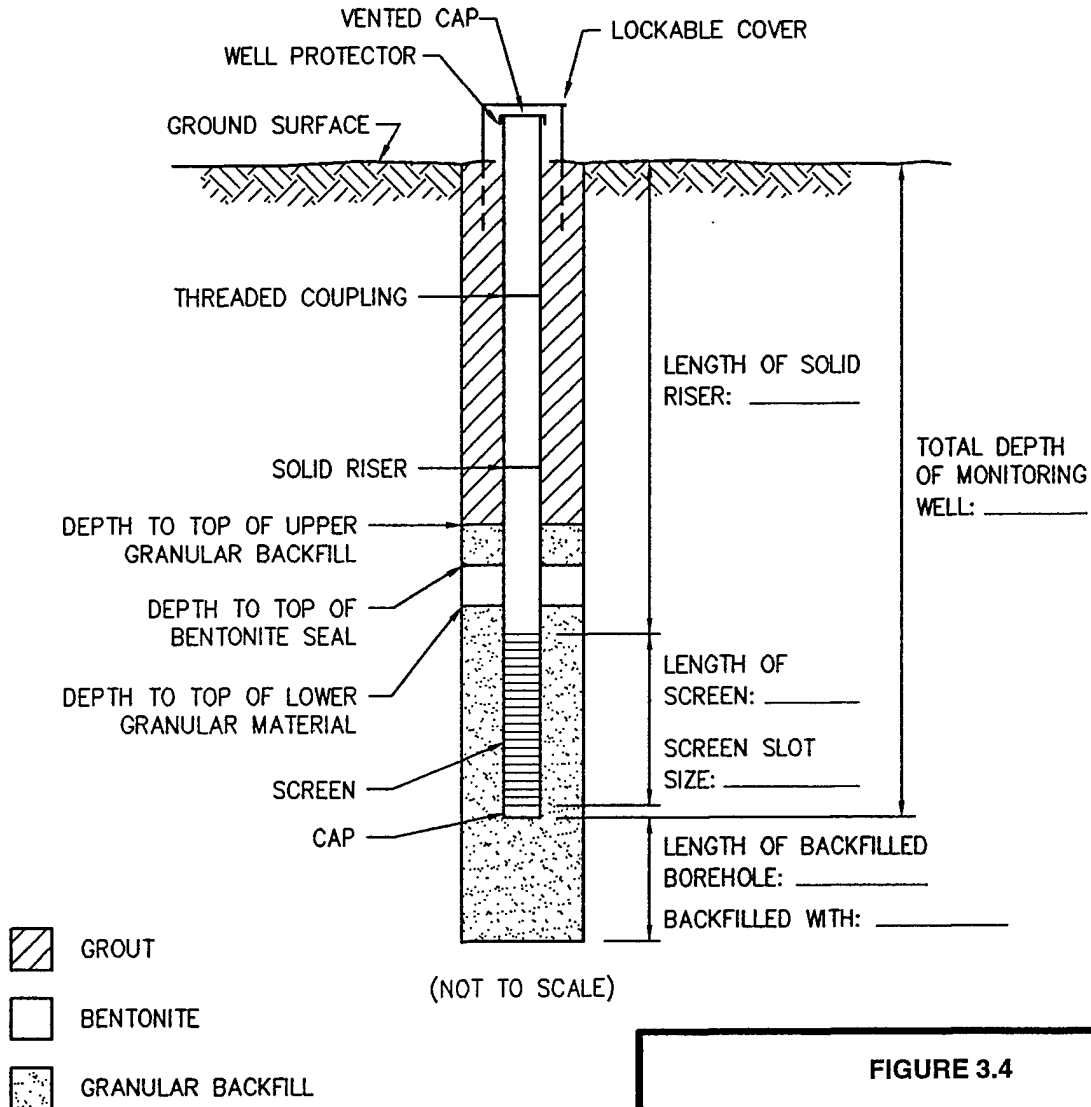
3.2.2.1.2 Stainless Steel Monitoring Points

If subsurface conditions do not permit the boreholes to stay open (i.e., if the formation collapses in the hole), monitoring points constructed of stainless steel screens and 0.375-inch Teflon®-lined tubing will be installed. Should 0.5-inch-ID PVC shallow monitoring points not be installed, the only resulting data gap will be the lack of water level information for that particular location. The decision to install monitoring points constructed from stainless steel and Teflon®-lined tubing will be made in the field once the open-hole stability of subsurface soils and Geoprobe® equipment can be evaluated.

The stainless steel monitoring points will be installed in boreholes punched using the Geoprobe®. These monitoring points will be constructed of a sacrificial drive point attached to a length of 0.5-inch-diameter stainless steel mesh that will function as the well screen, which in turn will be connected to 0.375-inch Teflon®-lined tubing.

MONITORING WELL INSTALLATION RECORD

JOB NAME OFFUTT AIR FORCE BASE WELL NUMBER _____
 JOB NUMBER 722450.24 INSTALLATION DATE _____ LOCATION _____
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL 2" SCH 40 PVC SLOT SIZE 0.01"
 RISER DIAMETER & MATERIAL 2" SCH 40 PVC BOREHOLE DIAMETER 8 INCHES
 GRANULAR BACKFILL MATERIAL _____ ES REPRESENTATIVE _____
 DRILLING METHOD HOLLOW STEM AUGER DRILLING CONTRACTOR _____



STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 MEASURED ON _____

FIGURE 3.4

MONITORING WELL INSTALLATION RECORD

Building 301
 Intrinsic Remediation TS
 Offutt Air Force Base, Nebraska

PARSONS
ENGINEERING SCIENCE, INC.
 Denver, Colorado

To install the stainless steel monitoring points, the borehole is punched and sampled to several feet above the target depth for the monitoring point. The probe rods are withdrawn from the borehole, and the soil sampler is replaced with the well point assembly. An appropriate length of Teflon[®]-lined tubing is threaded through the probe rods and attached to the well point. The assembly is lowered into the borehole and then driven down to the target depth and sampling zone. The probe rods are removed, leaving the sacrificial tip, screen assembly, and tubing behind. The soil is likely to cave in around the screen and tube assembly; where this does not occur, silica sand will be emplaced to create a sand pack around the well point, and the borehole annular space around the tubing above the sand pack will be filled with granular bentonite or grout to seal it. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4).

3.2.2.1.3 Temporary Monitoring Points

Where site conditions do not allow a permanent monitoring point to be constructed (i.e., in an active agricultural field), then a temporary monitoring point will be installed, completed, sampled, and abandoned. The PVC casing and screen or Teflon[®] tubing will be extracted as far as possible and discarded. While holes created by the Geoprobe[®] may cave in soon after extraction of the drive rod, any test holes remaining open after extraction of the casing will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater (see also Section 3.3.2.5).

3.2.2.2 Monitoring Well Advancement and Installation Procedures

Monitoring wells will be advanced using a truck-mounted drilling rig equipped with 4.25-inch-ID HSAs. During borehole advancement, soil samples for visual description will be collected at a frequency sufficient to identify the depths of significant stratigraphic contacts (e.g., contacts between fill material and loess, between loess and glacial outwash, and between glacial outwash and glacial till). Sampling intervals will be determined on the basis of stratigraphic information collected by WCC (1993 and

1996), and by observing drill cuttings and drilling action. Soil samples will be obtained using a split-spoon sampling device or another similar method judged to be acceptable by the Parsons ES field scientist.

During drilling, it may be necessary to maintain a head of potable water or bentonite slurry in the HSAs during augering in order to prevent heaving of loose, poorly-cohesive sands and gravels into the augers during borehole advancement. If this procedure is necessary, the introduced fluids will be pumped out of the HSAs to the extent possible following borehole completion and well string installation. The remainder of the fluid will be removed from the subsurface during development activities (Section 3.2.5).

Upon completion of drilling to the proper termination depth, monitoring well casing and screen will be installed through the HSAs. Well construction details will be noted on a Monitoring Well Installation Record form similar to that shown for monitoring points in Figure 3.4. This information will become part of the permanent field record for the site.

Well screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 2 inches. Screens will be factory-slotted with 0.010-inch openings, and will be fitted with a bottom plug. The estimated depth of the midpoint of the screen for each well is indicated on Table 3.2. However, the position may be field-modified after consideration is given to the geometry and hydraulic characteristics of the stratum in which the well will be screened.

Blank riser pipe will be constructed of Schedule 40 PVC with an ID of 2 inches. All well casing sections will be flush-threaded; glued joints will not be used. Wells that will project above the ground surface will be fitted with a vented PVC top cap to maintain ambient atmospheric pressure within the well casing.

The field scientist will verify and record the borehole depth, the lengths of all casing sections, and the depth to the top of all well completion materials placed in the annulus

between the casing and the borehole wall. All lengths and depths will be measured to the nearest 0.1 foot.

A graded filter pack consisting of 8-12 or 16-30 silica sand will be placed around the screened interval and will extend at least 2 feet above the top of the screen. A two-foot-thick sodium bentonite pellet seal will be placed on top of the sand filter pack and hydrated (if placed above the water table) with potable water. The pellet seal will be overlaid with a Portland® cement/sodium bentonite grout that will extend from the top of the pellet seal to approximately 5 feet bgs. The grout will consist of one 94-pound sack of cement and about 5 pounds of bentonite for each 7 gallons of water used. The bentonite content of the cement/bentonite mixture will not exceed 8 percent by dry weight. The grout will be overlaid with concrete that will extend to the ground surface.

Each monitoring well and point will be completed flush with the ground surface or projecting above the ground surface as directed by Base personnel. The casing of projecting wells will be cut off approximately 2 feet above the ground surface and capped with a vented cap. A steel protective casing will be installed to a minimum depth of 2 to 3 feet into the concrete. The protective casing will contain a weep hole near its base to prevent accumulation of water in the casing. Three concrete-filled steel guard posts will be placed in concrete around the protective casing if the well is in danger of being damaged by vehicular traffic or other activities. A 2-foot by 2-foot by 4-inch concrete pad that slopes away from the well will be constructed around the protective casing. Casings for flush-mount wells will be cut approximately 3 inches bgs and capped to prevent infiltration of surface water. A manhole-style protective casing consisting of a cast iron valve box assembly will be placed around the casing, and cemented in place using concrete that will be blended to the existing pavement. In areas where pavement is not already present, a concrete pad (as described above) will be constructed around the protective casing to facilitate runoff during precipitation events. After monitoring well/point completion or abandonment, each site will be restored as closely as possible to its original condition.

3.2.3 Collection of Soil Samples for Field Screening and Laboratory Analysis During Monitoring Well/Point Drilling

Soil samples will be collected at 5-foot intervals throughout the vadose zone during drilling of wells MW13 and MW14, which are located in or near potential contamination source areas (Figure 3.1). A portion of each sample will be used to measure the total ionizable VOC concentration in soil headspace using a PID. Each headspace screening sample will be placed in a clean, sealed plastic bag or mason jar and allowed to equilibrate to the ambient temperature for at least 15 minutes. The PID probe will then be inserted into the bag or jar, and the maximum reading will be recorded in the field records. If headspace readings that are significantly above background readings are obtained, indicating the presence of vadose zone contamination, then the sample will be submitted to a laboratory for analysis of VOCs using the method specified in Table 3.1. Each laboratory soil sample will be placed in an analyte-appropriate sample container and hand-delivered to the USEPA field laboratory personnel for analysis. If USEPA personnel have not mobilized to the site, then the samples will be shipped on ice to the NRMRL via overnight courier.

Soil samples for TOC analysis will also be collected from selected monitoring well/point boreholes located in uncontaminated or minimally contaminated areas cross-gradient or downgradient from the CAH plume. One sample for TOC analysis will be collected from each major lithologic unit encountered in the saturated zone during advancement of wells MW15, MW17, MW18, and MW14 (Figure 3.1). One TOC sample will also be collected from each major lithologic unit encountered in the saturated zone during advancement of monitoring points MP5 through MP9.

3.2.4 Equipment Decontamination During Drilling and Soil Sampling Activities

Prior to arriving at the site, and between each sampling location, probe rods, tips, sleeves, pushrods, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination.

When collecting soil samples for laboratory analysis of VOCs, the sampling device will be disassembled and decontaminated with Alconox[®] and potable water between each soil sample. The barrel will then be rinsed with deionized water and a solvent (methanol or isopropanol), air-dried, and reassembled with new liners. Between uses, the sampling barrel will be wrapped in clean plastic or foil to prevent contamination. Prior to collection of samples for TOC analysis, the sampling device will be rinsed with potable water and scrubbed with a stiff brush, as necessary, to remove soil particles from previous sampling intervals.

All rinseate will be collected for transportation and proper disposal by Base personnel. Alternate methods of rinseate disposal will be considered by the Parsons ES field scientist as recommended by Base personnel. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.2.5 Monitoring Point Development and Records

The newly installed monitoring points and wells will be developed prior to sampling to remove fine sediments and introduced fluids from the portion of the formation adjacent to the screened interval. Development of monitoring points will be accomplished using a peristaltic pump provided by USEPA NRMRL or Parsons ES. Development of monitoring wells will be accomplished using an electric submersible pump and, if necessary to obtain acceptable water clarity, a surging device. Monitoring point development will occur a minimum of 24 hours prior to sampling.

Development will continue until a minimum of 10 casing volumes for monitoring points and 15 casing volumes for monitoring wells have been removed, and the water pH, temperature, and specific conductance have stabilized. If the development water is still turbid after removal of the minimum number of casing volumes, development will continue until the water becomes clear or the turbidity of the water produced has been stable after the removal of several additional casing volumes. In low-yield wells that go dry during development, development activity will be staged over a period of time

to allow water to refill the well bore. In the event that the minimum number of casing volumes cannot be removed, the water volume recovered and the deficiency will be noted in the development records.

A development record will be maintained for each monitoring point and well. The development record will be completed in the field by the field scientist. Figure 3.5 is an example of a development record used for similar well installations. Development records will include:

- Monitoring point/well number;
- Date and time of development;
- Development method;
- Monitoring point/well depth;
- Volume of water produced;
- Description of water produced;
- Post-development water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

Development waters will be collected and held for proper disposal by Base personnel. Alternate methods of water disposal will be considered by the Parsons ES field scientist as recommended by Base personnel.

MONITORING POINT DEVELOPMENT RECORD

Job Number: 722450.24

Job Name: AFCEE-Remediation by Natural Attenuation

Location Offutt AFB, Nebraska

by _____ Date: _____

Well Number _____ Measurement Datum _____

Pre-Development Information

Time (Start): _____

Water Level: _____ Total Depth of Well: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature(°C) _____
Specific Conductance(μS/cm) _____

Interim Water Characteristics

Gallons Removed _____

pH _____

Temperature (°C) _____

Specific Conductance(μS/cm) _____

Post-Development Information

Time (Finish): _____

Water Level: _____ Total Depth of Well: _____

Approximate Volume Removed: _____

Water Characteristics

Color _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material _____
pH _____ Temperature(°C) _____
Specific Conductance(μS/cm) _____

Comments:

FIGURE 3.5

MONITORING WELL DEVELOPMENT RECORD

Building 301
Intrinsic Remediation TS
Offutt Air Force Base, Nebraska

**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

3.2.6 Location and Datum Survey

The location and elevation of all groundwater grab samples, newly installed monitoring wells and monitoring points, and surface water/sediment sampling locations not previously surveyed will be surveyed soon after completion. At least one previously installed well also will be surveyed to ensure that the survey ties into previously conducted surveys, and at least one major cultural feature, such as a building corner will be surveyed. Horizontal coordinates will be measured to the nearest 0.1 foot relative to state plane coordinates. The elevation of the ground surface adjacent to the protective casing will be measured relative to the USGS msl datum. The ground surface elevation will be measured to the nearest 0.1 foot. A top-of-casing datum for wells and points constructed of PVC casing and screen will be measured to the nearest 0.01 foot. Because water levels cannot be measured through the monitoring point tubing, no datum elevation, such as top of casing, will be measured for monitoring points constructed with Teflon[®] tubing.

3.2.7 Water Level Measurements

Water levels at existing and newly installed monitoring wells and PVC monitoring points will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe.

3.3 GROUNDWATER SAMPLING

This section describes the scope of work required for collection of groundwater quality samples. Samples will be collected from selected previously installed monitoring wells and all newly installed groundwater monitoring points and wells. Previously installed wells targeted for sampling include B301-MW1, -MW2S/2D, -MW-6, -MW7S/7I/7D, -MW8I, -MW9S/9I, MW10, MW11, MW12, and TW-1 (Figure 3.1). A peristaltic pump with dedicated high-density polyethylene (HDPE) tubing will be used to collect groundwater samples at all monitoring points and from all wells with a sufficiently shallow water level. Samples from the remaining wells having

deeper water levels will be collected using a dedicated disposable polyethylene bailer attached to a dedicated nylon or polyethylene rope. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parson ES and the USEPA NRMRL who are trained in the performance of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference. Groundwater sampling includes the following activities:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well/point integrity including:
 - Protective cover, cap, and lock,
 - External surface seal and pad,
 - Monitoring point stick-up, cap, and datum reference, and
 - Internal surface seal;
- Groundwater sampling, including:
 - Water level measurements,
 - Visual inspection of sample water,
 - Monitoring point/well casing evacuation, and
 - Sample collection;
- Sample preservation and shipment, including:

- Sample preparation,
- Onsite measurement of physical parameters, and
- Sample labeling;
- Completion of sampling records; and
- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.3.1 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.1.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the Geoprobe® sampling tools, sampling/purging pumps, nondisposable bailers, water level probe and cable, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Given the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with isopropyl alcohol;
- Rinse with distilled or deionized water; and

- Air dry.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling record (Figure 3.6).

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the USEPA mobile laboratory's permanent record of the sampling event.

3.3.1.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for onsite measurements of DO, pH, electrical conductivity, temperature, ORP, sulfate, nitrate, ferrous iron (Fe^{2+}), and other field parameters listed on Table 3.1.

3.3.2 Well and Monitoring Point Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples through contact with improperly cleaned equipment. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.1.1. Dedicated tubing will be used at each well or monitoring point developed, purged, and/or sampled with the peristaltic pump. Pumps and nondisposable bailers will be decontaminated according to procedures listed in Section 3.3.1.1. In addition to the use of properly cleaned equipment, a clean pair of new, disposable nitrile or latex gloves will be worn each time a different well or monitoring point is sampled.

The following paragraphs present the procedures to be followed for groundwater sample collection from groundwater monitoring wells and monitoring points. These activities will be performed in the order presented below. Exceptions to this procedure

GROUNDWATER SAMPLING RECORD

SAMPLING LOCATION _____

SAMPLING DATE(S) _____

MONITORING WELL _____

(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.

SAMPLE COLLECTED BY: _____ of _____

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT _____

STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: _____

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT _____

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☐ EQUIPMENT CLEANED BEFORE USE WITH _____
Items Cleaned (List): _____

2 ☐ PRODUCT DEPTH _____ FT. BELOW DATUM
Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM
Measured with: _____

3 ☐ WATER-CONDITION BEFORE WELL EVACUATION (Describe):
Appearance: _____
Odor: _____
Other Comments: _____

4 ☐ WELL EVACUATION:
Method: _____
Volume Removed: _____
Observations: Water (slightly - very) cloudy
Water level (rose - fell - no change)
Water odors: _____
Other comments: _____

FIGURE 3.6

GROUNDWATER SAMPLING RECORD

Building 301
Intrinsic Remediation TS
Offutt Air Force Base, Nebraska

**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

MONITORING WELL

[] Bailer made of: _____
[] Pump, type: _____
[] Other, describe: _____

Temp: _____ ° _____	Measured with: _____
pH: _____	Measured with: _____
Conductivity: _____	Measured with: _____
Dissolved Oxygen: _____	Measured with: _____
Redox Potential: _____	Measured with: _____
Salinity: _____	Measured with: _____
Nitrate: _____	Measured with: _____
Sulfate: _____	Measured with: _____
Ferrous Iron: _____	Measured with: _____
Other: _____	

[] Filtration: Method _____ Containers: _____
Method _____ Containers: _____
Method _____ Containers: _____

- ☐ Container Sides Labeled
- ☐ Container Lids Taped
- ☐ Containers Placed in Ice Chest

Denver, Colorado

will be noted in the field scientist's field notebook or on the groundwater sampling record (Figure 3.6).

3.3.2.1 Preparation of Location

Prior to starting the sampling procedure, the area around the existing wells and new monitoring points will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the monitoring well/point.

3.3.2.2 Water Level and Total Depth Measurements

Prior to removing water from the monitoring well or monitoring point, the static water level will be measured. An electric water level probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring well/point, and the depth will be measured to the nearest 0.01 foot. Alternatively, well construction records may be used to determine the well depths. Based on these measurements, the volume of water to be purged from the monitoring well/point will be calculated.

3.3.2.3 Monitoring Well/Point Purging

The volume of water contained within the monitoring well/point casing at the time of sampling will be calculated, and at least three times the calculated volume will be removed from the well/point. A peristaltic pump will be used for monitoring well and monitoring point purging, depth and volume permitting, and a bailer or electric submersible pump (e.g., a Grundfos Redi-Flo II® pump or Enviro-Tech® ES Series battery-operated purge pump), will be used to purge all monitoring wells in which a peristaltic pump cannot be used. All purge waters will be collected for proper disposal.

If a monitoring well/point is evacuated to a dry state during purging, the monitoring well/point will be allowed to recharge, and the sample will be collected as soon as sufficient water is present in the monitoring well/point to obtain the necessary sample

quantity. Sample compositing or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

3.3.2.4 Sample Extraction

Dedicated HDPE tubing and a peristaltic pump will be used to extract groundwater samples from monitoring wells/points wherever depth to groundwater permits; otherwise, a bailer will be used. The tubing, pump, or bailer will be lowered through the casing into the water gently to prevent splashing. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

Unless other instructions are given by the USEPA mobile laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be disposed of in the same manner as purge water.

3.3.2.5 Grab Sampling

In the event monitoring points are not installed, groundwater grab samples will be collected using the Geoprobe® apparatus. To collect these samples, a properly decontaminated, screened probe tip will be driven to the desired sampling depth. As it is driven to depth, the screen will be inside the probe rods. After reaching the desired depth, the outer rods will be withdrawn to expose the screen. Purging and sampling procedures will be identical to those for monitoring points. After sampling, the rods and screen will be withdrawn, and the holes will be abandoned as described in Section 3.2.2.1.3.

3.3.3 Onsite Groundwater Parameter Measurement

As indicated on Table 3.1, many of the groundwater chemical parameters will be measured onsite by USEPA staff at a mobile laboratory. Some of the measurements will be made with direct-reading meters, while others will be made using a Hach®

portable colorimeter in accordance with specific Hach® analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will have been cleaned prior to sample collection by thoroughly washing with a solution of laboratory-grade, phosphate-free detergent (e.g., Alconox®) and water, and rinsing with isopropyl alcohol and deionized water to prevent interference or cross-contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric or colorimetric methods, the analysis will be repeated by diluting the groundwater sample with distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled as to their contents and carefully stored for proper disposal.

3.3.3.1 Dissolved Oxygen Measurements

DO measurements will be made using a meter with a downhole oxygen sensor or a sensor in a flow-through cell before and immediately following groundwater sample acquisition. When DO measurements are taken in monitoring wells/points that have not yet been sampled, the existing monitoring wells/points will be purged until DO levels stabilize. The lowest stable DO reading will be recorded.

3.3.3.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected using the same technique as the samples taken for laboratory analyses. The measurements will be made in a flow-through cell or a clean glass container separate from those intended for laboratory analysis. The measured values will be recorded on the groundwater sampling record (Figure 3.8).

3.3.3.3 Oxidation/Reduction Potentials

The ORP of groundwater is an indication of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the ORP of a groundwater system depends upon and influences rates of biodegradation. ORPs can be used to provide real-time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The ORP of a groundwater sample taken inside the contaminant plume should be somewhat less than that taken in an upgradient location.

The ORP of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis or in a flow through cell.

3.3.3.4 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by USEPA NRMRL scientists via titrimetric analysis using USEPA-approved Hach® Method 8221 (0 to 5,000 mg/L as calcium carbonate) or a similar method. Alkalinity of the groundwater sample also will be measured in the laboratory using USEPA Method 310.1.

3.3.3.5 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced USEPA NRMRL scientists via colorimetric analysis using a Hach® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with Hach® Method 8039 (0 to 30.0 mg/L NO₃). Nitrite concentrations in groundwater samples will be analyzed after preparation with EPA-approved Hach® Method 8507 (0 to 0.35 mg/L NO₂) or a similar method. Alternatively, samples may be submitted for laboratory analysis using USEPA method 353.1 or its equivalent.

3.3.3.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in groundwater is a potential electron acceptor for biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. A USEPA NRMRL scientist will measure sulfate and sulfide concentrations via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. USEPA-approved Hach® Methods 8051 (0 to 70.0 mg/L SO₄) and 8131 (0.60 mg/L S²⁻) (or similar) will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively. Samples also may be submitted for laboratory analysis using a method such as Waters Capillary Electrophoresis Method N-601 or its equivalent.

3.3.3.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the ORP of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a Hach® DR/700 Portable Colorimeter after appropriate sample preparation. Hach® Method 8008 (or similar) for total soluble iron [0 to 3.0 mg/L ferric iron (Fe³⁺) + ferrous iron (Fe²⁺)] and Hach® Method 8146 (or similar) for ferrous iron (0 to 3.0 mg/L Fe²⁺) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.3.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantitated in the field using colorimetric analysis with a Hach® DR/700 Portable Colorimeter. USEPA-approved Hach® Method 8034 (0 to 20.0 mg/L Mn) or similar will be used for quantitation of manganese concentrations. Sample preparation and disposal procedures are outlined earlier in Section 3.3.3.

3.3.3.9 Carbon Dioxide Measurements

Carbon dioxide concentrations are of interest because carbon dioxide is a byproduct of all biodegradation reactions. In addition, carbon dioxide in groundwater is a potential electron acceptor for methanogenic biodegradation under anaerobic conditions. Carbon dioxide concentrations in groundwater will be measured in the field by USEPA NRMRL scientists via titrimetric analysis using Hach® Method 8223 (0 to 250 mg/L as CO₂), or similar. Sample preparation and disposal procedures are the same as outlined at the beginning of Section 3.3.3.

3.4 SURFACE WATER AND SEDIMENT SAMPLING

Five surface water and four sediment samples will be collected from the drainage ditch locations previously sampled by WCC (1993 and 1996) (Figure 3.1). The stations to be sampled will include SW1, SW2, SW3, SW5, and SW6, and SD1 through SD4. An additional surface water and sediment sample will be collected in the ditch approximately 250 feet south of station SW4/SD2 in order to assess upstream (background) conditions. In addition, a surface water and sediment sample will be collected from the boggy area in the vicinity of Geoprobe® borehole GS31 (just east of the western Base perimeter fence) if sufficient standing water is present. If sufficient water is not present, then only a sediment sample will be collected. Surface water samples will be analyzed for VOCs, and sediment samples will be analyzed for VOCs and TOC using the methods specified in Table 3.1.

Samples will be collected so as not to cause cross-contamination. Background samples will be collected first. Sampling will continue with the furthest downstream

station and proceed upstream to avoid sample contamination. The surface water sample at each location will be collected before the sediment sample in order to minimize the amount of suspended solids in the water sample. Samples will be taken from the active ditch bed on the ditch side nearest the source of contamination.

Surface water samples will be collected by submerging unpreserved sample containers in the ditch. If the water level is too shallow, a hole may be dug in the sediment to create room in the channel for containers to be submerged. The sediment will be allowed to settle before water samples are collected. Surface water samples may be collected by transferring water from the ditch to sample bottles using a decontaminated beaker. Sample bottles that contain preservative will be filled by first filling an unpreserved sample bottle or beaker as described above and transferring the sample into the preserved bottle. Temperature, pH, DO, and specific conductance will be measured at each surface water sampling point and recorded in the field logbook. Sediment samples will be collected from the upper 6 inches of ditch bottom sediment using a stainless steel hand trowel. During sediment collection, the amount of sediment disturbance will be minimized.

Surface water and sediment samples will be handled and transported in the same manner as groundwater and soil samples. All samples will be placed in the appropriate prelabeled containers with Teflon®-lined caps and stored on ice in an insulated cooler. The following physical environmental information will be recorded in the logbook for each site:

- Sample station location;
- The width, depth, and flow rate of streams;
- Surface water conditions (e.g., color, odor, etc.); and
- The location of any discharge pipes, sewers, or tributaries.

3.5 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples from the time of sampling until the samples are delivered to USEPA field laboratory.

3.5.1 Sample Preservation

The USEPA laboratory support personnel will add any necessary chemical preservatives prior to filling the sample containers. Samples will be prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature of as close to 4 °C as possible. Samples will be delivered promptly to USEPA field laboratory personnel, who will be responsible for shipment of appropriate samples to the NRMRL in Ada, Oklahoma for fixed-base laboratory analysis.

3.5.2 Sample Containers and Labels

Sample containers and appropriate container lids will be provided by the USEPA field laboratory (see Appendix B). The sample containers will be filled as described in Sections 3.1.2, 3.3.2.4, and 3.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., groundwater, soil);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and

- Requested analyses.

3.5.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to the onsite USEPA field laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container;
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the USEPA field laboratory. Delivery will occur as soon as possible after sample acquisition.

3.5.4 Chain-of-Custody Control

Chain-of-custody documentation for the shipment of samples from the USEPA field laboratory to the NRMRL analytical laboratory in Ada, Oklahoma, will be the responsibility of the USEPA field personnel.

3.5.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;

- Sampling method;
- Field observations of
 - Sample appearance, and
 - Sample odor;
- Weather conditions;
- Water level prior to purging (groundwater samples, only);
- Total monitoring well/point depth (groundwater samples, only);
- Sample depth (sediment and soil samples, only);
- Purge volume (groundwater samples, only);
- Water level after purging (groundwater samples, only);
- Monitoring well/point condition (groundwater samples, only);
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity (surface water and groundwater samples, only); and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form (Figure 3.6). Soil, sediment, and surface water sampling information will be recorded in the field log book.

3.5.6 Fixed-Base Laboratory Analyses

Fixed-base laboratory analyses will be performed on groundwater, soil, sediment, and surface water samples as well as the QA/QC samples described in Section 5. The

analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, USEPA NRMRL personnel will provide a sufficient number of analyte-appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with USEPA protocol or those listed in Appendix B of this plan.

USEPA laboratory support personnel will specify the necessary QC samples and prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory or USEPA NRMRL field personnel. Containers, ice chests with adequate padding, and cooling media will be provided by USEPA NRMRL laboratory personnel. Sampling personnel will fill the sample containers and return the samples to the field laboratory.

3.6 SURFACE WATER FLOW RATE MEASUREMENTS

Surface water flow rates will be measured at each surface water sampling station where there is measurable flow. At each measurement location, channel depth and width measurements will be taken. The method of flow measurement to be used will depend on channel conditions and estimated flow rates. Possible devices that can be used include a Pygmy Price® current meter, a cutthroat flume, or a floating object.

If a current meter is used, then the width of the stream channel at the point of measurement will be divided into 1-foot segments. A tape measure or surveyor's chain will be stretched and held in place across the channel and used to mark the segments. The depth of water will be measured in the center of each segment and recorded in the logbook. The surface water flow will be measured for each segment and recorded in the logbook. The current meter will be set to measure flow at a point in each segment that is centered within the segment at a depth of 0.6 of the total water depth, measured from the water surface.

Flow measurements made using a floating object are based on the time it takes the object to travel a premeasured distance. The width and depth of the water in the stream

channel are used to calculate the cross sectional area of flow, and the stream flow velocity is multiplied by the cross-sectional area to calculate the volumetric flow rate.

3.7 AQUIFER TESTING

3.7.1 Slug Tests

Slug tests were performed during the previous SI and RI (WCC, 1993 and 1996); therefore, extensive slug testing will not be performed as part of this field program. Slug tests will be conducted in a maximum of five newly installed 2-inch-ID monitoring wells to supplement the existing hydraulic conductivity database for the unconsolidated deposits affected by CAH contamination at the site. To the extent possible, tests will be performed in wells screened in a variety of geologic deposits to allow estimation of the range of hydraulic conductivities at the site. This information is required to accurately estimate the velocity of groundwater and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft²/day). Slug testing can be performed using either a rising head or a falling head test; at this site, both methods will be used in sequence.

3.7.1.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.
- **Slug Test.** Two types of testing are possible: rising head and falling head tests. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.

- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing, or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.7.1.2 Equipment

The following equipment will be used to conduct a slug test:

- Teflon[®], PVC, or metal slugs;
- Nylon or polypropylene rope;
- Electric water level indicator;
- Pressure transducer/sensor;
- Field logbook/forms; and
- Automatic data-recording instrument (such as the Hermit Environmental Data Logger[®], In-Situ, Inc. Model SE1000B, or equivalent).

3.7.1.3 General Test Methods

Slug tests are accomplished by either removing a slug or quantity of water (rising head) or introducing a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Slug testing will proceed only after well development has been performed and multiple water level measurements over time show that static water levels are in

equilibrium. During the slug test, the water level change should be influenced only by the introduction (or removal) of the slug volume. Other factors, such as inadequate well development or extended pumping may lead to inaccurate results; in addition, slug tests will not be performed on wells with free product. The field scientist will determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other downhole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.3.1.1.

3.7.1.4 Falling Head Test

The falling head test is the first step in the two-step slug testing procedure. The following steps describe procedures to be followed during performance of the falling head test.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are equipped with watertight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the aquifer slug test data form (Figure 3.7) with entries for:
 - Borehole/well number,
 - Project number,
 - Project name,
 - Aquifer testing team,
 - Climatic data,
 - Ground surface elevation,

Aquifer Slug Test Data Sheet

Location <u>Offut Air Force Base</u>	Client <u>AFCEE</u>	Well No. _____
Job No. <u>722450.24</u>	Field Scientist _____	Date _____
Water Level _____	Total Well Depth _____	
Measuring Datum _____	Elevation of Datum _____	
Weather _____	Temp _____	
Comments _____		

[illegible]**FIGURE 3.7**

AQUIFER TEST DATA FORM

Building 301
Intrinsic Remediation TS
Offutt Air Force Base, Nebraska

**PARSONS
ENGINEERING SCIENCE, INC.**

Denver, Colorado

- Top of well casing elevation,
 - Identification of measuring equipment being used,
 - Page number,
 - Static water level, and
 - Date.
4. Measure the static water level in the well to the nearest 0.01 foot.
 5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
 6. Lower the decontaminated slug into the well to just above the water level in the well.
 7. Turn on the data logger and quickly lower the slug below the water table, being careful not to disturb the pressure transducer. Follow the owner's manual for proper operation of the data logger.
 8. Terminate data recording when the water level stabilizes in the well. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.7.1.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedure.

1. Measure the water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.

2. Initiate data recording and quickly withdraw the slug from the well. Follow the owner's manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well, and remove the pressure transducer from the well and decontaminate. The well will be considered stabilized for termination purposes when it has recovered 80 to 90 percent from the initial displacement.

3.7.1.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using the AQTESOLV™ software package (Geraghty & Miller Modeling Group, 1994) and the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions.

SECTION 4

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field and trip blanks; decontamination of all equipment that contacts the sample medium before and after each use; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the USEPA laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and sample containers will be packaged in coolers with ice to maintain a temperature of as close to 4°C as possible.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 4.1.

QA/QC sampling will include collection and analysis of duplicate groundwater, surface water, and replicate soil/sediment samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve the analysis of laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

TABLE 4.1
QA/QC SAMPLING PROGRAM
BUILDING 301
 INTRINSIC REMEDIATION TS
 OFFUTT AFB, NEBRASKA

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	4 Groundwater/Surface Water and 1 Soil/Sediment Samples (10%) ^{a/}	VOCs
Rinseate Blanks	2 Samples (5 % of Groundwater/Surface Water Samples)	VOCs
Field Blanks	2 Samples (5 % of Groundwater/Surface Water Samples)	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	One per sampling event	VOCs
Laboratory Control Sample	One per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	One per method per medium	Laboratory Control Charts (Method Specific)

^{a/} Actual frequency of QA/QC samples may be altered by the USEPA field scientist.

^{b/} Number of replicate soil samples will increase if more than 4 soil samples are collected.

Duplicate water and replicate soil samples will be collected at a frequency of 1 for every 10 or fewer samples of similar matrix. Refer to Table 3.1 and Appendix B for further details on sample volume requirements.

One rinseate sample will be collected for every 20 or fewer water and soil/sediment samples collected. Rinseate samples will be obtained for the various environmental media sampled as described below:

- Rinseate samples for groundwater sampling will be obtained by pouring distilled water through a new disposable bailer or pumping distilled water through new peristaltic pump tubing, and transferring the water into a sample container provided by the laboratory.
- Rinseate samples for surface water sampling will be obtained by pouring distilled water into the decontaminated sampling device (e.g., beaker) and transferring the water into a sample container provided by the laboratory.
- Rinseate samples for soil/sediment sampling will be obtained by pouring distilled water through or over the decontaminated sampling device (e.g., split spoon for soils or stainless steel trowel for sediments) and into a sample container provided by the laboratory.

Rinseate samples will be analyzed for VOCs only.

A field blank will be collected for every 20 or fewer water samples (from surface water, groundwater monitoring point, and groundwater monitoring well sampling events) to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions on sampling results during the transportation of samples. The trip blank will be prepared by the

laboratory. A trip blank will be transported inside each cooler which contains samples for VOC analysis. Trip blanks will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs. LCSs and LMBs will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used (see Table 3.1).

SECTION 5

DATA ANALYSIS AND REPORT

Once the data collected during the field effort are assembled, they will be analyzed using a variety of methods. For example, isopleth maps of CAHs, degradation products, and alternate electron acceptors and donors will be used to evaluate the occurrence and mechanisms of biodegradation at the site, using the relationships discussed in Section 2. In addition, the Thiessen method will be used to estimate contaminant mass in the plume, using data from the latest sampling event and from previous sampling events. The Thiessen method also may be used to evaluate movement of the center of mass of the CAH plume over time, as presented by Dupont *et al.* (1996a and 1996b). This information will give an indication of how the plume has changed over time, and whether the plume is stable. If it is apparent that contaminant mass is lost over time, then it is highly likely that biodegradation is occurring. Site contaminant data also will be used to determine rates of contaminant mass loss, and in conjunction with microcosm data, to determine rates of biodegradation. Site data also will be used to estimate contaminant flux through specified areas. Where applicable, the data also will be applied to estimate the impacts of other ongoing or planned remedial actions at the B301 SWMU.

After the data evaluation and analysis, numerical and/or analytical groundwater models will be used to evaluate the fate and transport of chlorinated solvents dissolved in groundwater at the site. The contaminant fate and transport modeling effort has three primary objectives: 1) predict the future extent and concentration of dissolved contaminant plumes by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) assess the possible exposure of potential downgradient receptors to contaminant concentrations that exceed levels intended to be protective of human health

and the environment; and 3) to provide technical support for selection of RNA as the best remedial alternative at regulatory negotiations, as appropriate.

Based upon model predictions of contaminant concentrations and distribution through time, and upon potential exposure pathways, the potential threat to human health and the environment will be assessed. If it is shown that RNA of CAHs at the site is sufficient to reduce the potential risk to human health and the environment to acceptable levels, Parsons ES will recommend implementation of the RNA option. If RNA is chosen, Parsons ES will prepare site-specific, LTM plans that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the RNA option is deemed inappropriate for use at the site, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are inappropriate, planned and potential remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate combination of remedial options will be recommended. Potential remedial options include, but are not limited to, groundwater pump-and-treat, enhanced biological treatment, air sparging, and *in situ* reactive barrier walls. The reduction in dissolved contaminant concentrations that should result from remedial activities will be used to produce new input files for the groundwater models. The models will then be used to predict the plume (and risk) reduction that should result from remedial actions.

A report detailing the results of the modeling and remedial option evaluation will be prepared. This report will follow the outline presented in Table 5.1 and will contain an introduction, site descriptions, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the suggested remedial approach for each site. This report will also contain the results of the site characterization activities described herein.

TABLE 5.1
EXAMPLE REPORT OUTLINE
Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

INTRODUCTION

Scope and Objectives
Site Background

SITE CHARACTERIZATION ACTIVITIES

Sampling and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Surface Features
Regional Geology and Hydrogeology
Site Geology and Hydrogeology
Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION

Source Characterization
Soil and Source Chemistry (Optional, if source is located)
Residual Contamination
Total Organic Carbon
Groundwater Chemistry
Dissolved Contamination
Groundwater Geochemistry
Discussion of Results
Evidence of Biodegradation/Cometabolism
Calculation of Biodegradation Rates
Expressed Assimilative Capacity

GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELING

Model Description
Conceptual Model Design and Assumptions
Initial Model Setup
Model Calibration
Sensitivity Analysis
Model Results
Conclusions

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Remedial Alternatives Evaluation Criteria
Long-Term Effectiveness
Implementability (Technical, Administrative)
Cost (Capital, Operating, Present Worth)
Factors Influencing Alternatives Development
Program Objectives
Contaminant Properties
Site-Specific Conditions

TABLE 5.1 (Continued)
EXAMPLE REPORT OUTLINE
Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Brief Description of Remedial Alternatives
 Intrinsic Remediation with Long-Term Monitoring
 Other Alternatives
Evaluation of Alternatives
Recommended Remedial Approach

LONG-TERM MONITORING PLAN

Overview
Monitoring Networks
Groundwater and Surface Water Sampling

CONCLUSIONS AND RECOMMENDATIONS

APPENDICES: Supporting Data and Documentation
 Site-Specific Model Input and Results

SECTION 6

REFERENCES

- Alvarez-Cohen, L.M. and McCarty, P.L., 1991a, Effects of toxicity, aeration, and reductant supply on trichloroethylene transformation by a mixed methanotrophic culture: Appl. Environ. Microbiol., vol. 57, no. 1, p. 228-235.
- Alvarez-Cohen, L.M., and McCarty, P.L., 1991b, Product toxicity and cometabolic competitive inhibition modeling of chloroform and trichloroethylene transformation by methanotrophic resting cells: Appl. Environ. Microbiol., vol. 57, no. 4, p. 1031-1037.
- American Water Works Association, 1995, Standard Methods for the Examination of Water and Wastewater. 19th Edition.
- Arciero, D., Vannelli, T., Logan, M., and Hooper, A.B., 1989, Degradation of trichloroethylene by the ammonia-oxidizing bacterium *Nitrosomonas europaea*: Biochem. Biophys. Res. Commun., vol. 159, p. 640-643.
- Black & Veatch Waste Science and Technology Corporation, 1990, Draft Corrective Measure Study--15% Submittal, Fire Protection Training Area 3, Offutt AFB, Nebraska, May.
- Bradley, P.M., and Chapelle, F.H., 1996, Anaerobic mineralization of vinyl chloride in Fe(III)-reducing aquifer sediments: Accepted for publication in Environmental Science and Technology, 1996.
- Bouwer, E.J., Rittman, B.E., and McCarty, P.L., 1981, Anaerobic degradation of halogenated 1- and 2-carbon organic compounds: Environ. Sci. Technol., vol. 15, no. 5, p. 596-599.
- Bouwer, E.J. and Wright, J.P., 1988, Transformations of trace halogenated aliphatics in anoxic biofilm columns: J. Contam. Hydrol., vol. 2, p. 155-169.
- Bouwer, E.J., 1994, Bioremediation of chlorinated solvents using alternate electron acceptors. In: Handbook of Bioremediation. CRC Press, Boca Raton, FL.
- Bouwer, H., 1989, The Bouwer and Rice slug test - an update: Ground Water, 27(3), p. 304-309.

- Bouwer, H., and Rice, R.C., 1976, A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells: *Water Resources Research*, 12(3), p. 423-428.
- Cline, P.V., and Delfino, J.J., 1989, Transformation kinetics of 1,1,1-trichloroethane to the stable product 1,1-dichloroethene, In: *Biohazards of Drinking Water Treatment*. Lewis Publishers, Inc. Chelsea, MI. p. 47-56.
- DeStefano, T.D., Gossett, J.M., and Zinder, S.H., 1991, Reductive dechlorination of high concentrations of tetrachloroethene to ethene by an anaerobic enrichment culture in the absence of methanogenesis: *Appl. Environ. Microbiol.*, vol. 57, no. 8, p. 2287-2292.
- Dupont, R.R., Gorder, K., Sorensen, D.L., and Kemblowski, M., 1996a, Assessment and quantification of intrinsic remediation at a chlorinated solvent/hydrocarbon contaminated site, Eielson AFB, Alaska: In: *Conference on Intrinsic Remediation of Chlorinated Solvents*. Salt Lake City, UT. April 2, 1996.
- Dupont, R.R., Gorder, K., Sorensen, D.L., and Kemblowski, M., 1996b, Field evaluation of intrinsic remediation at a chlorinated solvent/hydrocarbon contaminated site, Eielson AFB, Alaska: In: *Conference on Intrinsic Remediation of Chlorinated Solvents*. Salt Lake City, UT. April 2, 1996.
- Engineering-Science, Inc. (ES), 1993, Health and Safety Plan for the Bioplume Modeling Initiative. Prepared for the Air Force Center for Environmental Excellence, Environmental Restoration Division, USAF Contract F41624-92-D-8036.
- Folsom, B.R., Chapman, P.J., and Pritchard, P.H., 1990, Phenol and trichloroethylene degradation by *Pseudomonas cepacia* G4: Kinetics and interactions between substrates: *Appl. Environ. Microbiol.*, vol. 56, no. 5, p. 1279-1285.
- Freedman, D.L., and Gossett, J.M., 1989, Biological reductive dechlorination of tetrachloroethylene and trichloroethylene to ethylene under methanogenic conditions: *Appl. Environ. Microbiol.*, vol. 55, no. 4, p. 1009-1014.
- Harker, A.R., and Kim, Y., 1990, Trichloroethylene degradation by two independent aromatic-degrading pathways in *Alcaligenes eutrophus* JMP134: *Appl. Environ. Microbiol.*, vol. 56, no. 4, p. 1179-1181.
- Hartmans, S., and de Bont, J.A.M., 1992, Aerobic vinyl chloride metabolism in *Mycobacterium aurum* Li: *Appl. Environ. Microbiol.*, vol. 58, no. 4, p. 1220-1226.

- Henry, S.M., 1991, Transformation of Trichloroethylene by Methanotrophs from a Groundwater Aquifer. Ph.D. Thesis. Stanford University. Palo Alto, California.
- Johnson, A.I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials: USGS Water-Supply Paper 1662-D.
- Kampbell, D.H., Wilson, J.T., and Vandergrift, S.A., 1989, Dissolved oxygen and methane in water by a GC headspace equilibrium technique: Intern. J. Environ. Analytical Chem., v. 36, p. 249 - 257.
- Lee, M.D. 1988. Biorestitution of aquifers contaminated with organic compounds. CRC Critical Reviews in Environmental Control, v. 18. p. 29-89.
- Little, C.D., Palumbo, A.V., Herbes, S.E., Lidstrom, M.E., Tyndall, R.L., and Gilmer, P.J., 1988, Trichloroethylene biodegradation by a methane-oxidizing bacterium: Appl. Environ. Microbiol., vol. 54, no. 4, p. 951-956.
- Mayer, K.P., Grbic-Galic, D., Semprini, L., and McCarty, P.L., 1988, Degradation of trichloroethylene by methanotrophic bacteria in a laboratory column of saturated aquifer material: Wat. Sci. Tech. (Great Britain), vol. 20, no. 11/12, p. 175-178.
- McCarty, P.L., Roberts, P.V., Reinhard, M., and Hopkins, G., 1992, Movement and transformations of halogenated aliphatic compounds in natural systems, In: Fate of Pesticides and Chemicals in the Environment. Ed., J.L. Schnoor. John Wiley & Sons, Inc. New York, New York. p. 191-209.
- McCarty, P.L., and Semprini, L., 1994, Ground-Water Treatment for Chlorinated Solvents, In: Handbook of Bioremediation. Lewis Publishers, Boca Raton, FL. 1994.
- Miller, R.E., and Guengerich, F.P., 1982, Oxidation of trichloroethylene by liver microsomal cytochrome P-450: Evidence for chlorine migration in a transition state not involving trichloroethylene oxide: Biochemistry, vol. 21, p. 1090-1097.
- Murray, W.D. and Richardson, M., 1993, Progress toward the biological treatment of C₁ and C₂ halogenated hydrocarbons: Critical Reviews in Environmental Science and Technology, v. 23, no. 3, pp. 195-217.
- Nelson, M.J.K., Montgomery, S.O., O'Neill, E.J., and Pritchard, P.H., 1986, Aerobic metabolism of trichloroethylene by a bacterial isolate: Appl. Environ. Microbiol., vol. 52, no. 2, p. 949-954.
- Parsons Engineering Science, Inc., 1994, Work Plan for an Engineering Evaluation/Cost Analysis in Support of the Intrinsic Remediation (Natural

Attenuation) Option, Tank 349 and Fire Protection Training Area 3, Offutt Air Force Base, Omaha, Nebraska. October.

Parsons Engineering Science, Inc., 1995, Treatability Study in Support of Intrinsic Remediation for Fire Protection Area 3, Offutt Air Force Base, Nebraska. May.

US Geological Survey (USGS), 1984a, 7.5 Minute Quadrangle Map of Omaha South, Nebraska-Iowa.

US Geological Survey (USGS), 1984b, 7.5 Minute Quadrangle Map of Plattsmouth, Nebraska-Iowa.

van Genuchten, M. T., and Alves, W. J., 1982, Analytical Solutions of the One-Dimensional Convective-Dispersive Solute Transport Equation: US Department of Agriculture, Technical Bulletin Number 1661, 151p.

Vogel, T.M., 1994, Natural Bioremediation of Chlorinated Solvents, In: Handbook of Bioremediation. Lewis Publishers, Boca Raton, FL. 1994.

Vogel, T.M., and McCarty, P.L., 1985, Biotransformation of tetrachloroethylene to trichloroethylene, dichloroethylene, vinyl chloride, and carbon dioxide under methanogenic conditions: Applied Environmental Microbiology, v. 49, no. 5, pp. 1080-1083.

Walton, W.C., 1988, Practical Aspects of Ground Water Modeling, 3rd Edition.

Wexler, E.J., 1992, Analytical solutions for one-, two-, and three-dimensional solute transport in ground-water systems with uniform flow: United States Geological Survey, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter B7, 190p.

Wiedemeier, T.H., Benson, L.A., Wilson, J.T., Kampbell, D.H., Hansen, J.E., and Miknis, R., 1996, Patterns of natural attenuation of chlorinated aliphatic hydrocarbons at Plattsburgh Air Force Base, New York: In: Conference on Intrinsic Remediation of Chlorinated Solvents. Salt Lake City, UT. April 2, 1996.

Wilson, J.T., and Wilson, B.H., 1985, Biotransformation of trichloroethylene in soil: Appl. Environ. Microbiol., vol. 49, no. 1, p. 242-243.

Woodward-Clyde Consultants, 1992a, Installation Restoration Program Remedial Investigation/Feasibility Study, Project Work Plan, Volume IV - Community Relations Plan, Offutt Air Force Base, Omaha, Nebraska. August.

Woodward-Clyde Consultants, 1992b, Installation Restoration Program, Groundwater Monitoring Program 1991-1992, Offutt Air Force Base, Omaha, Nebraska. November.

Woodward-Clyde Consultants, 1993, Installation Restoration Program, Site Inspection,
Offutt Air Force Base, Omaha, Nebraska. November.

Woodward-Clyde Consultants, 1996, Unpublished Remediation Investigation Data.

APPENDIX A

LABORATORY ANALYTICAL DATA FROM WCC (1993 AND 1996)

APPENDIX A CONTENTS

- A.1 Summary of Chemicals Detected in SI Groundwater Samples from Monitoring Wells
- A.2 Summary of Chemicals Detected in SI Subsurface Soil Samples
- A.3 Summary of Chemicals Detected in SI Surface (Manhole) Water Samples
- A.4 Summary of Chemicals Detected in SI Sediment Samples
- A.5 Summary of RI Geoprobe® Water Sample Analytical Results
- A.6 Comparison of RI Field Analytical Results with Laboratory Analytical Results
- A.7 Summary of RI HydroPunch® Analytical Results
- A.8 Summary of RI Monitoring Well Analytical Results
- A.9 Summary of RI Soil Analytical Results

TABLE A.1
SUMMARY OF CHEMICALS DETECTED IN SI GROUNDWATER
SAMPLES FROM MONITORING WELLS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (MW) HITS ONLY 07:11:51									
Lab Sample Number: WCC Sample Number: Collect Date:	Units	019027-0004-SA B301-001-MW-001 18-Nov-91		019098-0001-SA B301-002-MW-001 19-Nov-91		019053-0002-SA B301-003-MW-001 19-Nov-91		019027-0001-SA B301-004-MW-001 18-Nov-91	
		Value	RL	Value	RL	Value	RL	Value	RL
8240-VOLS									
Bromodichloromethane	µg/L	- U	5	3.6 J	5	- U	5	- U	5
Carbon tetrachloride	µg/L	11	5	- U	5	- U	5	- U	5
Chloroform	µg/L	1.9 J	5	16	5	16	5	- U	5
Dibromochloromethane	µg/L	- U	5	2 J	5	- U	5	- U	5
1,2-Dichloroethene (total)	µg/L	11	5	- U	5	- U	5	- U	5
Trichloroethene	µg/L	40	5	- U	5	- U	5	- U	5
Trichlorofluoromethane	µg/L	- U	5	- U	5	- U	5	- U	5
METAL									
Thallium	mg/L	- U	.01	- U	.02	.0026 J	.01	- U	.005
Arsenic	mg/L	- U	.01	.0038 J	.01	.006	.005	.016	.005
Barium	mg/L	.29	.01	.48	.01	.54	.01	.91	.01
Beryllium	mg/L	- U	.002	- U	.002	- U	.002	.0032	.002
Chromium	mg/L	.063	.01	.075	.01	.093	.01	.06	.01
Cobalt	mg/L	.012 J	.01	.012	.01	.013	.01	.011	.01
Copper	mg/L	- U	.02	.031	.02	- U	.028	.061	.02
Lead	mg/L	- U	.01	.012	.005	.012	.005	.038	.005
Nickel	mg/L	.013 J	.04	.049	.04	.11	.04	.066	.04
Vanadium	mg/L	.0088 J	.01	.046	.01	.055	.01	.09	.01
Zinc	mg/L	.019 J	.02	.085	.02	.099	.02	.21	.02
Calcium	mg/L	69.7	.2	95.3	.2	99.6	.2	131	.2
Iron	mg/L	2.6	.1	21.5	.1	26.8	.1	59.3	.1
Magnesium	mg/L	36.8	.2	23.8	.2	26.3	.2	56.4	.2
Potassium	mg/L	5.1	5	7	5	7.7	5	20.3	5
Sodium	mg/L	.18.3	5	49.5	5	44.1	5	14	5
Manganese	mg/L	.12	.01	.48	.01	.47	.01	.55	.01
GEN-INORGANIC									
Alkalinity, Total	mg/L	314	5	220	5	390	5	505	5
Alkalinity, Bicarb	mg/L	314	5	220	5	390	5	505	5
Chloride	mg/L	11.2	3	91.9	3	10.9	3	- U	3
Nitrate plus Nitrite	mg/L	3.3	.2	.45	.1	4.7	.5	.13	.1
Sulfide, Total	mg/L	- U	.05	.63	.25	.16	.1	.47	.25
Sulfate	mg/L	17.4	5	43.3	5	11.7	5	24.9	5
Total Dissolved Solids	mg/L	406	10	537	10	489 J	10	691	10

B = Analyte detected in blank
J = Estimated Value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

Source: WCC, 1993.

TABLE A.1 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI GROUNDWATER
SAMPLES FROM MONITORING WELLS

Building 301
 Intrinsic Remediation TS
 Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (MW) HITS ONLY 07:11:51									
Lab Sample Number:		019027-0002-SA		019027-0003-SA		019027-0005-SA			
WCC Sample Number:		B301-005-MW-001		B301-006-MW-001		B301-02D-MW-001			
Collect Date:		18-Nov-91		18-Nov-91		18-Nov-91			
	Units	Value	RL	Value	RL	Value	RL		
8240-VOLS									
Bromodichloromethane	µg/L	- U	5	- U	5	- U	5	- U	5
Carbon tetrachloride	µg/L	1.1 J	5	- U	5	- U	5	- U	5
Chloroform	µg/L	- U	5	- U	5	- U	5	- U	5
Dibromochloromethane	µg/L	- U	5	- U	5	- U	5	- U	5
1,2-Dichloroethene (total)	µg/L	- U	5	- U	5	- U	5	- U	5
Trichloroethene	µg/L	- U	5	- U	5	- U	5	- U	5
Trichlorofluoromethane	µg/L	- U	5	1.8 J	5	- U	5	- U	5
METAL									
Thallium	mg/L	- U	.005	- U	.005	.0013 J	.005	.0013 J	.005
Arsenic	mg/L	.011	.005	.011	.005	.013	.01	.013	.01
Barium	mg/L	.76	.01	.31	.01	.4	.01	.4	.01
Beryllium	mg/L	- U	.002	- U	.002	- U	.002	- U	.002
Chromium	mg/L	.058	.01	.034	.01	.0095 J	.01	.0095 J	.01
Cobalt	mg/L	.019	.01	- U	.01	- U	.01	- U	.01
Copper	mg/L	.045	.02	.013 J	.02	- U	.02	- U	.02
Lead	mg/L	.022	.01	- U	.01	.0092 J	.01	.0092 J	.01
Nickel	mg/L	.075	.04	.043	.04	- U	.04	- U	.04
Vanadium	mg/L	.072	.01	.01	.01	- U	.01	- U	.01
Zinc	mg/L	.15	.02	.027	.02	.026	.02	.026	.02
Calcium	mg/L	99.6	.2	114	.2	84.8	.2	84.8	.2
Iron	mg/L	35.9	.1	4.3	.1	2.8	.1	2.8	.1
Magnesium	mg/L	38	.2	17.7	.2	23	.2	23	.2
Potassium	mg/L	11.4	5	3.6 J	5	4.3 J	5	4.3 J	5
Sodium	mg/L	17	5	22.3	5	23.9	5	23.9	5
Manganese	mg/L	1.5	.01	.11	.01	.28	.01	.28	.01
GEN-INORGANIC									
Alkalinity, Total	mg/L	330	5	181	5	367	5	367	5
Alkalinity, Bicarb	mg/L	330	5	181	5	367	5	367	5
Chloride	mg/L	12	3	68.6	3	3.9	3	3.9	3
Nitrate plus Nitrite	mg/L	5.1	1	27.9	2	- U	.1	- U	.1
Sulfate, Total	mg/L	.34	.25	- U	.05	- U	.05	- U	.05
Sulfate	mg/L	36	5	57.7	5	10.7	5	10.7	5
Total Dissolved Solids	mg/L	496	10	609	10	370	10	370	10

B = Analyte detected in blank
 J = Estimated value
 Q = Value may not be site-related
 R = Rejected value
 RL = Reporting limit
 U = Nondetected
 Semi-Vols = Appendix IX semivolatile organics
 Vols = Appendix IX volatile organics

TABLE A.2
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Lab Sample Number: WCC Sample Number: Collect Date:	Units	02/27/92 AR02 - Trend Report - 8301 (SB) Hits Only 07:16:24				017231-0003-SA				017231-0002-SA				017231-0001-SA				017297-0002-SA			
		8301-001-SB-002				18-Sep-91				19-Sep-91				19-Sep-91				20-Sep-91			
		Value	RL	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL
8240-VOLS																					
Acrylonitrile	µg/kg	2.9 J	110	- U	130	- U	130	- U	130	- U	120	- U	120	- U	110	- U	110	- U	110	- U	110
2-Butanone (MEK)	µg/kg	- U	11	37	13	37	13	37	13	37	13	37	13	37	13	37	13	37	13	37	13
1,2-Dichloroethane	µg/kg	3.6 J	5.4	5.1 J	6.3	5.1 J	6.3	5.1 J	6.3	5.1 J	6.3	5.1 J	6.3	5.1 J	6.3	5.1 J	6.3	5.1 J	6.3	5.1 J	6.3
Tetrachloroethene	µg/kg	- U	5.4	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3
Toluene	µg/kg	- U	5.4	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3	- U	6.3
8270-SEMI-VOLS																					
Acenaphthene	µg/kg	- U	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Anthracene	µg/kg	37 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Benzo(a)anthracene	µg/kg	160 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Benzo(b)fluoranthene	µg/kg	200 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Benzo(k)fluoranthene	µg/kg	73 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Benzo(g,h,i)perylene	µg/kg	110 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Benzo(a)pyrene	µg/kg	110 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Chrysene	µg/kg	150 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Dibenz(a,h)anthracene	µg/kg	- U	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Di-n-butyl phthalate	µg/kg	83 Jq	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
bis(2-Ethylhexyl)phthalate	µg/kg	- U	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Fluoranthene	µg/kg	310 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Fluorene	µg/kg	- U	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Indeno(1,2,3-cd)pyrene	µg/kg	90 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Phenanthrene	µg/kg	180 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
Pyrene	µg/kg	290 J	360	- U	2100	- U	2100	- U	2100	- U	400	- U	400	- U	360	- U	360	- U	360	- U	360
8080-PEST/PCB																					
Aldrin	µg/kg	- U	18	- U	2.1	- U	2.1	- U	2.1	- U	2.1	- U	2.1	- U	1.9	- U	1.9	- U	1.9	- U	1.9
4,4'-DDE	µg/kg	71	36	- U	4.1	- U	4.1	- U	4.1	- U	4	- U	4	- U	3.6	- U	3.6	- U	3.6	- U	3.6
4,4'-DDT	µg/kg	75	36	- U	4.1	- U	4.1	- U	4.1	- U	4	- U	4	- U	3.6	- U	3.6	- U	3.6	- U	3.6
Endosulfan sulfate	µg/kg	- U	36	- U	4.1	- U	4.1	- U	4.1	- U	4	- U	4	- U	3.6	- U	3.6	- U	3.6	- U	3.6
ORGANIC-OTHER																					
Total Petroleum Hydrocarbons	mg/kg	23.8	21.6	- U	25.1	- U	25.1	- U	25.1	- U	24.3	- U	24.3	- U	21.8	- U	21.8	- U	21.8	- U	21.8

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

Source: WCC, 1993.

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

		02/27/92 AR02 - Trend Report - B301 (SB) Hits Only 07:16:24									
		017231-0003-SA		017231-0002-SA		017231-0001-SA		017297-0002-SA			
Lab Sample Number:		B301-001-SB-002		B301-001-SB-020		B301-001-SB-052		B301-002-SB-002			
Collect Date:		18-Sep-91		19-Sep-91		19-Sep-91		20-Sep-91			
	Units	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL
METAL											
Thallium	mg/kg	.28 J	1.1	.34 J	1.3	.22 J	1.2	.25 J	1.1		
Arsenic	mg/kg	5.9	.54	7.3	.63	3.3	.61	2	1.1		
Antimony	mg/kg	211	1.1	- U	7.5	- U	7.3	- U	6.6		
Barium	mg/kg	.62	1.1	236	1.3	1.2	1.2	180	1.1		
Beryllium	mg/kg	1.2	.22	.65	.25	.69	.24	.62	.22		
Cadmium	mg/kg	14.1	.54	1.3	.63	1	.61	13.6	.55		
Chromium	mg/kg	7	1.1	13.1	1.3	11.1	1.2	6.7	1.1		
Cobalt	mg/kg	17.4	1.1	7.5	1.3	7.6	1.2	14.1	1.1		
Copper	mg/kg	32.3	2.2	18.3	2.5	12.7	2.4	14.2	2.2		
Lead	mg/kg	18.8	2.7	78.4	6.3	8.3	3	31.8	2.7		
Nickel	mg/kg	- U	4.3	20.9	5	20.4	4.9	- U	4.4		
Silver	mg/kg	8.3 J	1.1	- U	1.3	- U	1.2	- U	1.1		
Tin	mg/kg	27.6	10.8	7.7 J	12.6	6.2 J	12.2	6.9 J	10.9		
Vanadium	mg/kg	68.1	1.1	31	1.3	27	1.2	28.4	1.1		
Zinc	mg/kg	9930	2.2	72.9	2.5	40.2	2.4	49	2.2		
Calcium	mg/kg	16400	21.6	10800	25.1	3110	24.3	6390	21.8		
Iron	mg/kg	5880	10.8	16600	12.6	13900	12.2	15300	10.9		
Magnesium	mg/kg	2040	21.6	5700	25.1	4470	24.3	4980	21.8		
Potassium	mg/kg	101 J	540	2480	628	1720	608	1810	546		
Sodium	mg/kg	639	1.1	117 J	628	73.5 J	608	79.5 J	546		
Manganese	mg/kg	- U	.11	578	1.3	1710	1.2	709	1.1		
Mercury	mg/kg			- U	.13	- U	.12	- U	.11		

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vole = Appendix IX volatile organics
Semi-Vole = Appendix IX semivolatile organics

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - 8301 (SB) Hits Only 07:16:24											
Lab Sample Number: WCC Sample Number: Collect Date:	Units	017297-0003-SA 8301-002-SB-020 20-Sep-91		017297-0001-SA 8301-002-SB-051 23-Sep-91		017405-0001-SA 8301-003-SB-002 25-Sep-91		017405-0002-SA 8301-003-SB-006 25-Sep-91			
		Value	RL	Value	RL	Value	RL	Value	RL	Value	RL
8240-VOLS											
Acrylonitrile	µg/kg	- U	120	- U	120	- U	110	- U	120	- U	120
2-Butanone (MEK)	µg/kg	- U	12	- U	12	- U	11	- U	12	- U	12
1,2-Dichloroethane	µg/kg	2.1 J	6	1.4 J	6	2.6 J	5.5	3.2 J	5.9	3.2 J	5.9
Tetrachloroethene	µg/kg	- U	6	- U	6	- U	5.5	- U	5.9	- U	5.9
Toluene	µg/kg	- U	6	- U	6	- U	5.5	- U	5.9	- U	5.9
8270-SEMI-VOLS											
Acenaphthene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Anthracene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Benzo(a)anthracene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Benzo(b)fluoranthene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Benzo(k)fluoranthene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Benzo(g,h,i)perylene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Benzo(a)pyrene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Chrysene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Dibenz(a,h)anthracene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Di-n-butyl phthalate	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
bis(2-Ethylhexyl)phthalate	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Fluoranthene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Fluorene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Indeno(1,2,3-cd)pyrene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Phenanthrene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
Pyrene	µg/kg	- U	400	- U	400	- U	370	- U	390	- U	390
8080-PEST/PCB											
Aldrin	µg/kg	- U	2	- U	2	- U	3.8	- U	2	- U	2
4,4'-DDE	µg/kg	- U	4	- U	4	41	7.3	9	3.9	9	3.9
4,4'-DDT	µg/kg	- U	4	- U	4	- U	7.3	- U	3.9	- U	3.9
Endosulfan sulfate	µg/kg	- U	4	- U	4	- U	7.3	- U	3.9	- U	3.9
ORGANIC-OTHER											
Total Petroleum Hydrocarbons	mg/kg	- U	24	- U	.24	310	22.2	- U	23.4	- U	23.4

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SB) Hits Only 07:16:24									
Lab Sample Number: WCC Sample Number: Collect Date:	Units	017297-0003-SA B301-002-SB-020 20-Sep-91		017297-0001-SA B301-002-SB-051 23-Sep-91		017405-0001-SA B301-003-SB-002 25-Sep-91		017405-0002-SA B301-003-SB-006 25-Sep-91	
		Value	RL	Value	RL	Value	RL	Value	RL
METAL									
Thallium	mg/kg	.22 J	1.2	.3 J	1.2	- U		- U	
Arsenic	mg/kg	3.8	.6	3.4	.6	5.8	.55	7.1	.59
Antimony	mg/kg	- U	7.2	- U	7.2	2.3 J	.66	3 J	5.9
Barium	mg/kg	192	1.2	135	1.2	258	1.1	225	1.2
Beryllium	mg/kg	.61	.24	.8	.24	.72	.22	.58	.23
Cadmium	mg/kg	- U	.6	- U	.6	.5 J	.55	.84	.59
Chromium	mg/kg	12.1	1.2	12.9	1.2	14.2	1.1	11.9	1.2
Cobalt	mg/kg	6	1.2	5.6	1.2	9.1	1.1	10.5	1.2
Copper	mg/kg	14.5	2.4	11.6	2.4	20.9	2.2	18.7	2.3
Lead	mg/kg	9.4	.6	9.6	.6	140	27.7	16.1	5.9
Nickel	mg/kg	16.2	4.8	15.5	4.8	19.2	4.4	23.5	4.7
Silver	mg/kg	- U	1.2	- U	1.2	.44 J	1.1	.56 J	1.2
Tin	mg/kg	4.9 J	12	5.1 J	12.1	- U	11.1	- U	11.7
Vanadium	mg/kg	28.4	1.2	24.3	1.2	26.8	1.1	25	1.2
Zinc	mg/kg	47.5	2.4	39	2.4	82.3	2.2	57.6	2.3
Calcium	mg/kg	23400	24	4210	24.1	7220	22.2	15200	23.4
Iron	mg/kg	14600	12	13000	12.1	16000	11.1	16600	11.7
Magnesium	mg/kg	6520	24	3610	24.1	4000	22.2	9640	23.4
Potassium	mg/kg	2080	600	1940	603	2330	554	1990	586
Sodium	mg/kg	124 J	600	61.7 J	603	- U	554	64.6 J	586
Manganese	mg/kg	371	1.2	355	1.2	574	1.1	799	1.2
Mercury	mg/kg	- U	.12	- U	.12	- U	.11	.17	.12

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
 Intrinsic Remediation TS
 Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SB) Hits Only 07:16:24											
Lab Sample Number: WCC Sample Number: Collect Date:		017405-0003-SA B301-003-SB-056 25-Sep-91		017695-0005-SA B301-004-SB-002 07-Oct-91		017695-0006-SA B301-004-SB-018 07-Oct-91		017695-0007-SA B301-004-SB-046 07-Oct-91			
	Units	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL
8240-VOLS											
Acrylonitrile	µg/kg	- U	110	- U	110	- U	120	- U	130	- U	130
2-Butanone (MEK)	µg/kg	- U	11	- U	11	- U	12	- U	13	- U	13
1,2-Dichloroethane	µg/kg	- U	5.6	- U	5.5	- U	5.8	- U	6.3	- U	6.3
Tetrachloroethene	µg/kg	- U	5.6	- U	5.5	- U	5.8	- U	6.3	- U	6.3
Toluene	µg/kg	- U	5.6	- U	5.5	- U	5.8	- U	6.3	- U	6.3
8270-SEMI-VOLS											
Acenaphthene	µg/kg	- U	370	280 J	1800	- U	380	- U	410	- U	410
Anthracene	µg/kg	- U	370	800 J	1800	- U	380	- U	410	- U	410
Benzo(a)anthracene	µg/kg	- U	370	2600	1800	- U	380	- U	410	- U	410
Benzo(b)fluoranthene	µg/kg	- U	370	2900	1800	- U	380	- U	410	- U	410
Benzo(k)fluoranthene	µg/kg	- U	370	1100 J	1800	- U	380	- U	410	- U	410
Benzo(g,h,i)perylene	µg/kg	- U	370	1300 J	1800	- U	380	- U	410	- U	410
Benzo(a)pyrene	µg/kg	- U	370	1800	1800	- U	380	- U	410	- U	410
Chrysene	µg/kg	- U	370	2500	1800	- U	380	- U	410	- U	410
Dibenz(a,h)anthracene	µg/kg	- U	370	250 J	1800	- U	380	- U	410	- U	410
Di-n-butyl phthalate	µg/kg	- U	370	- U	1800	- U	380	- U	410	- U	410
bis(2-Ethylhexyl)phthalate	µg/kg	- U	370	- U	1800	- U	380	- U	410	- U	410
Fluoranthene	µg/kg	- U	370	5100	1800	- U	380	- U	410	- U	410
Fluorene	µg/kg	- U	370	340 J	1800	- U	380	- U	410	- U	410
Indeno(1,2,3-cd)pyrene	µg/kg	- U	370	950 J	1800	- U	380	- U	410	- U	410
Phenanthrene	µg/kg	- U	370	3700	1800	- U	380	- U	410	- U	410
Pyrene	µg/kg	- U	370	5200	1800	- U	380	- U	410	- U	410
8080-PEST/PCB											
Aldrin	µg/kg	- U	1.9	- U	7.4	- U	2	- U	2.1	- U	2.1
4,4'-DDE	µg/kg	- U	3.7	6 J	14	- U	3.8	- U	4.1	- U	4.1
4,4'-DDT	µg/kg	- U	3.7	42	14	- U	3.8	- U	4.1	- U	4.1
Endosulfan sulfate	µg/kg	- U	3.7	19	14	- U	3.8	- U	4.1	- U	4.1
ORGANIC-OTHER											
Total Petroleum Hydrocarbons	mg/kg	- U	22.5	99.9	21.8	- U	23.3	- U	25.1	- U	25.1

B = Analyte detected in blank
 J = Estimated value
 Q = Value may not be site-related
 R = Rejected value
 RL = Reporting limit
 U = Nondetected
 Vols = Appendix IX volatile organics
 Semi-Vols = Appendix IX semivolatile organics

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SB) Hits Only 07:16:24									
Lab Sample Number:		017405-0003-SA		017695-0005-SA		017695-0006-SA		017695-0007-SA	
WCC Sample Number:		B301-003-SB-056		B301-004-SB-002		B301-004-SB-018		B301-004-SB-046	
Collect Date:		25-Sep-91		07-Oct-91		07-Oct-91		07-Oct-91	
	Units	Value	RL	Value	RL	Value	RL	Value	RL
METAL									
Thallium	mg/kg	- U	.56	.14 J	.55	.26 J	1.2	.24 J	1.3
Arsenic	mg/kg	2.4	.56	6.7	2.7	8.3	.58	6.8	1.3
Antimony	mg/kg	- U	6.7	- U	6.5	- U	7	- U	7.5
Barium	mg/kg	66.9	1.1	213	1.1	262	1.2	204	1.3
Beryllium	mg/kg	.43	.22	.56	.22	.73	.23	.56	.25
Cadmium	mg/kg	- U	.56	1.4	.55	1.2	.58	.82	.63
Chromium	mg/kg	6.9	1.1	14.2	1.1	13.4	1.2	11.4	1.3
Cobalt	mg/kg	4	1.1	6.4	1.1	8.6	1.2	6.7	1.3
Copper	mg/kg	6.5	2.2	17.4	2.2	21.2	2.3	16.2	2.5
Lead	mg/kg	4.3	.56	59	5.5	14.3	2.9	11.5	1.3
Nickel	mg/kg	8.8	4.5	17.7	4.4	23.9	4.7	17.8	5
Silver	mg/kg	.24 J	1.1	- U	1.1	- U	1.2	- U	1.3
Tin	mg/kg	- U	11.2	8.5 J	10.9	13.6	11.7	6.7 J	12.5
Vanadium	mg/kg	15.3	1.1	23.9	1.1	30	1.2	24.4	1.3
Zinc	mg/kg	18.1	2.2	68.9	2.2	65.7	2.3	54.6	2.5
Calcium	mg/kg	1750	22.5	15600	21.8	8630	23.3	5220	25.1
Iron	mg/kg	6680	11.2	15300	10.9	20000	11.7	15600	12.5
Magnesium	mg/kg	1660	22.5	4340	21.8	6710	23.3	4900	25.1
Potassium	mg/kg	918	561	1730	546	1870	583	2230	627
Sodium	mg/kg	- U	561	146 J	546	184 J	583	137 J	627
Manganese	mg/kg	230	1.1	632	1.1	668	1.2	787	1.3
Mercury	mg/kg	- U	.11	- U	.11	- U	.12	- U	.13

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Voile = Appendix IX volatile organics
Semi-Voile = Appendix IX semivolatile organics

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SB) Hits Only 07:16:24											
Lab Sample Number:	017736-0001-SA	017736-0002-SA	017736-0003-SA	017695-0002-SA							
WCC Sample Number:	B301-005-SB-003	B301-005-SB-010	B301-005-SB-041	B301-006-SB-003							
Collect Date:	08-Oct-91	09-Oct-91	09-Oct-91	07-Oct-91							
Units	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL	Value
8240-VOLS											
Acrylonitrile	µg/kg										
2-Butanone (MEK)	µg/kg	- U	240	- U	250	130	- U	130	- U	120	
1,2-Dichloroethane	µg/kg	- U	24	- U	25	13	- U	13	- U	12	
Tetrachloroethene	µg/kg	- U	12	- U	12	6.3	- U	6.3	- U	6	
Toluene	µg/kg	- U	12	- U	12	6.3	- U	6.3	- U	6	
	µg/kg	2.8 J	12	4.1 J	12	6.3	1.7 J	6.3	- U	6	
8270-SEMI-VOLS											
Acenaphthene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Anthracene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Benzo(a)anthracene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Benzo(b)fluoranthene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Benzo(k)fluoranthene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Benzo(g,h,i)perylene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Benzo(a)pyrene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Chrysene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Dibenz(a,h)anthracene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Di-n-butyl phthalate	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
bis(2-Ethylhexyl)phthalate	µg/kg	- U	400	1800 Q	410	420	- U	420	- U	400	
Fluoranthene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Fluorene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Indeno(1,2,3-cd)pyrene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Phenanthrene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
Pyrene	µg/kg	- U	400	- U	410	420	- U	420	- U	400	
8080-PEST/PCB											
Aldrin	µg/kg	- U	2.1	- U	2.1	2.1	- U	2.1	- U	2.1	
4,4'-DDE	µg/kg	- U	4	- U	4.1	4.2	- U	4.2	- U	4	
4,4'-DDT	µg/kg	- U	4	- U	4.1	4.2	- U	4.2	- U	4	
Endosulfan sulfate	µg/kg	- U	4	- U	4.1	4.2	- U	4.2	- U	4	
ORGANIC-OTHER											
Total Petroleum Hydrocarbons	mg/kg	- U	24.5	- U	24.6	25.2	- U	25.2	- U	24.2	

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

		02/27/92 AR02 - Trend Report - B301 (SB)Hite Only				07:16:24			
Lab Sample Number:		017736-0001-SA		017736-0002-SA		017736-0003-SA		017695-0002-SA	
UCC Sample Number:		B301-005-SB-003		B301-005-SB-010		B301-005-SB-041		B301-006-SB-003	
Collect Date:		08-Oct-91		09-Oct-91		09-Oct-91		07-Oct-91	
	Units	Value	RL	Value	RL	Value	RL	Value	RL
METAL									
Thallium	mg/kg	- U	.61	- U	.62	- U	.63	-12 J	1.2
Arsenic	mg/kg	8.1	3.1	8.8 J	.62	4	.63	3.1	.6
Antimony	mg/kg	- U	7.3	- R	.62	- U	7.6	- U	7.3
Barium	mg/kg	253	1.2	250	1.2	143	1.3	154	1.2
Beryllium	mg/kg	.6	.24	.55	.25	.68	.25	.68	.24
Cadmium	mg/kg	1.4	.61	1.2	.62	.87	.63	.8	.6
Chromium	mg/kg	9.6	1.2	10.5	1.2	14.2	1.3	14.4	1.2
Cobalt	mg/kg	8.4	1.2	9.2	1.2	5.8	1.3	6.3	1.2
Copper	mg/kg	20.1	2.4	18.7	2.5	12.1	2.5	14.5	2.4
Lead	mg/kg	14.1	1.2	14.7 J	6.2	9.9	.63	10.3	1.2
Nickel	mg/kg	23.6	4.9	22.9	4.9	16.4	5	17	4.8
Silver	mg/kg	- U	1.2	- U	1.2	- U	1.3	- U	1.2
Tin	mg/kg	13.1	12.2	14.2	12.3	9.7 J	12.6	6.9 J	12.1
Vanadium	mg/kg	23.8	1.2	24.2	1.2	23.5	1.3	25.5	1.2
Zinc	mg/kg	59.6	2.4	61.3	2.5	49.4	2.5	48.8	2.4
Calcium	mg/kg	16700	24.5	15700	24.6	4320	25.2	3910	24.2
Iron	mg/kg	16700	12.2	16700	12.3	15100	12.6	15300	12.1
Magnesium	mg/kg	9390	24.5	10400	24.6	3970	25.2	4440	24.2
Potassium	mg/kg	1740	612	2000	616	1700	630	2320	605
Sodium	mg/kg	234 J	612	209 J	616	89.8 J	630	101 J	605
Manganese	mg/kg	950	1.2	898	1.2	461	1.3	391	1.2
Mercury	mg/kg	- U	.12	- U	.12	- U	.13	- U	.12

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Voile = Appendix IX volatile organics
Semi-Voile = Appendix IX semivolatile organics

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SB) Hits Only 07:16:24									
Lab Sample Number:		017695-0003-SA		017695-0004-SA		019352-0001-SA			
WCC Sample Number:		B301-006-SB-006		B301-006-SB-041		B301-M43-SB-011			
Collect Date:		07-Oct-91		07-Oct-91		26-NOV-91			
	Units	Value	RL	Value	RL	Value	RL		
8240-VOLS									
Acrylonitrile	µg/kg	- U	120	- U	120	-	-		
2-Butanone (MEK)	µg/kg	- U	12	- U	12	-	-		
1,2-Dichloroethane	µg/kg	- U	6	- U	6.2	-	-		
Tetrachloroethene	µg/kg	- U	6	- U	6.2	-	-		
Toluene	µg/kg	- U	6	- U	6.2	-	-		
8270-SEMI-VOLS									
Acenaphthene	µg/kg	- U	400	- U	410	-	-		
Anthracene	µg/kg	- U	400	- U	410	-	-		
Benzo(a)anthracene	µg/kg	- U	400	- U	410	-	-		
Benzo(b)fluoranthene	µg/kg	- U	400	- U	410	-	-		
Benzo(k)fluoranthene	µg/kg	- U	400	- U	410	-	-		
Benzo(g,h,i)perylene	µg/kg	- U	400	- U	410	-	-		
Benzo(a)pyrene	µg/kg	- U	400	- U	410	-	-		
Chrysene	µg/kg	- U	400	- U	410	-	-		
Dibenz(a,h)anthracene	µg/kg	- U	400	- U	410	-	-		
Di-n-butyl phthalate	µg/kg	- U	400	- U	410	-	-		
bis(2-Ethylhexyl)phthalate	µg/kg	- U	400	- U	410	-	-		
Fluoranthene	µg/kg	- U	400	- U	410	-	-		
Fluorene	µg/kg	- U	400	- U	410	-	-		
Indeno(1,2,3-cd)pyrene	µg/kg	- U	400	- U	410	-	-		
Phenanthrene	µg/kg	- U	400	- U	410	-	-		
Pyrene	µg/kg	- U	400	- U	410	-	-		
8080-PEST/PCB									
Aldrin	µg/kg	- U	2.1	- U	2.1	-	-		
4,4'-DDE	µg/kg	- U	4	- U	4.1	-	-		
4,4'-DDT	µg/kg	- U	4	- U	4.1	-	-		
Endosulfan sulfate	µg/kg	- U	4	- U	4.1	-	-		
ORGANIC-OTHER									
Total Petroleum Hydrocarbons	mg/kg	- U	24.2	- U	24.7	- U	26.5		

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

TABLE A.2 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN SI
SUBSURFACE SOIL SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SB) Hits Only 07:16:24									
Lab Sample Number:		017695-0003-SA		017695-0004-SA		019352-0001-SA			
WCC Sample Number:		B301-006-SB-006		B301-006-SB-041		B301-MJ3-SB-011			
Collect Date:		07-Oct-91		07-Oct-91		26-NOV-91			
	Units	Value	RL	Value	RL	Value	RL	Value	RL
METAL									
Thallium	mg/kg	- U	1.2	.16 J	1.2	-	-	-	-
Arsenic	mg/kg	3.9	.6	2.7	.62	-	-	-	-
Antimony	mg/kg	- U	7.2	- U	7.4	-	-	-	-
Barium	mg/kg	147	1.2	159	1.2	-	-	-	-
Beryllium	mg/kg	.63	.24	.76	.25	-	-	-	-
Cadmium	mg/kg	.74	.6	.55 J	.62	-	-	-	-
Chromium	mg/kg	12	1.2	11.2	1.2	-	-	-	-
Cobalt	mg/kg	6.3	1.2	5.4	1.2	-	-	-	-
Copper	mg/kg	12.6	2.4	13.5	2.5	-	-	-	-
Lead	mg/kg	11	1.2	9.3	.62	-	-	-	-
Nickel	mg/kg	16	4.8	17	4.9	-	-	-	-
Silver	mg/kg	- U	1.2	- U	1.2	-	-	-	-
Tin	mg/kg	6.2 J	12.1	5.2 J	12.4	-	-	-	-
Vanadium	mg/kg	25.3	1.2	23.1	1.2	-	-	-	-
Zinc	mg/kg	44.8	2.4	43.1	2.5	-	-	-	-
Calcium	mg/kg	3530	24.2	4520	24.7	-	-	-	-
Iron	mg/kg	13800	12.1	12900	12.4	-	-	-	-
Magnesium	mg/kg	3610	24.2	4110	24.7	-	-	-	-
Potassium	mg/kg	1610	604	2430	618	-	-	-	-
Sodium	mg/kg	93.3 J	604	133 J	618	-	-	-	-
Manganese	mg/kg	490	1.2	427	1.2	-	-	-	-
Mercury	mg/kg	- U	.12	- U	.12	-	-	-	-

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

TABLE A.3
SUMMARY OF CHEMICALS DETECTED IN SI
SURFACE (MANHOLE) WATER SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

		02/27/92 AR02 - Trend Report - B301 (SU) Hits Only 07:25:38									
		019263-0001-SA B301-MH1-SW-001 25-NOV-91		019379-0003-SA B301-MH3-SW-001 02-DEC-91		019379-0001-SA B301-MH4-SW-001 02-DEC-91		019408-0006-SA B301-MH5-SW-001 03-DEC-91			
		Value	RL	Value	RL	Value	RL	Value	RL		
		Units		Units		Units		Units			
8240-VOLS											
Bromodichloromethane	µg/L	- U	5	8.5	5	8.6	5	- U	5		
Chloroform	µg/L	- U	5	13	5	11	5	- U	5		
Dibromochloromethane	µg/L	- U	5	- U	5	4.7 J	5	- U	5		
Toluene	µg/L	- U	5	1.7 J	5	1.6 J	5	- U	5		
8080-PEST/PCB											
4,4'-DDD	µg/L	- U	.1	- U	.1	- U	.1	- U	.1		
4,4'-DDE	µg/L	- U	.1	- U	.1	- U	.1	.072 J	.1		
ORGANIC-OTHER											
Total Petroleum Hydrocarbons	mg/L	- U	1	- U	1	- U	1	36.1	10		
METAL											
Thallium	mg/L	.0014 J	.01	- U	.005	- U	.01	- U	.01		
Arsenic	mg/L	- U	.005	.0075	.005	- U	.005	.31	.025		
Barium	mg/L	.023	.01	.064	.01	.046	.01	.25	.01		
Cadmium	mg/L	- U	.005	- U	.005	- U	.005	.03	.005		
Chromium	mg/L	- U	.01	- U	.01	- U	.01	.14	.01		
Cobalt	mg/L	- U	.01	- U	.01	- U	.01	.015	.01		
Copper	mg/L	.018 J	.02	.011 J	.02	.013 J	.02	1.3	.02		
Lead	mg/L	.027	.01	- U	.005	- U	.005	5.8	2.5		
Nickel	mg/L	- U	.04	- U	.04	.0064 J	.04	.047	.04		
Silver	mg/L	- U	.01	- U	.01	.014	.01	.0065 J	.01		
Tin	mg/L	- U	.1	- U	.1	- U	.1	1.9	.1		
Vanadium	mg/L	- U	.01	.0089 J	.01	- U	.01	.014	.01		
Zinc	mg/L	.21	.02	.036	.02	.061	.02	.014	.02		
Calcium	mg/L	.22	.2	42.4	.2	45.3	.2	47.9	.2		
Iron	mg/L	.48	.1	.11	.1	.32	.1	6	.1		
Magnesium	mg/L	2.3	.2	10.9	.2	7.7	.2	10.3	.2		
Potassium	mg/L	1.4 J	5	7.2	5	11.5	5	8.3	5		
Sodium	mg/L	21	5	61.8	5	41.6	5	72.4	5		
Manganese	mg/L	.024	.01	.0072 J	.01	.045	.01	.097	.01		
Mercury	mg/L	- U	.0002	- U	.0002	- U	.0002	.00049	.0002		

B = Analyte detected in blank
 J = Estimated value
 Q = Value may not be alter-related
 R = Rejected value
 RL = Reporting limit
 U = Nondetected
 Vols = Appendix IX volatile organics
 Semi-Vols = Appendix IX semivolatile organics

TABLE A.4
SUMMARY OF CHEMICALS DETECTED IN
SI SEDIMENT SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SD) Hits Only 07:21:38																	
Lab Sample Number: WCC Sample Number: Collect Date:		020697-0001-SA B301-001-SD-000 30-Jan-92				019352-0002-SA B301-MH1-SD-001 26-Nov-91				019408-0003-SA B301-MH2-SD-001 03-Dec-91				019379-0002-SA B301-MH3-SD-001 02-Dec-91			
	Units	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL		
8240-VOLS																	
Acetone	µg/kg	- U	13	35 q	25	- U	14	- U	13	- U	13	- U	13	- U	13		
2-Butanone (MEK)	µg/kg	- U	13	2.6 J	25	- U	14	- U	13	- U	13	- U	13	- U	13		
Methylene chloride	µg/kg	- U	6.4	3.5 J	12	- U	6.8	- U	6.8	- U	6.8	- U	6.8	- U	6.7		
Toluene	µg/kg	- U	6.4	5.3 J	12	- U	6.8	- U	6.8	- U	6.8	- U	6.8	- U	6.7		
Xylenes (total)	µg/kg	1.3 J	6.4	- U	12	- U	6.8	- U	6.8	- U	6.8	- U	6.8	- U	6.7		
8270-SEMI-VOLS																	
Acenaphthene	µg/kg	130 J	840	- U	2000	- U	2000	5900 J	22000	- U	22000	- U	22000	- U	440		
Anthracene	µg/kg	250 J	840	- U	2000	- U	2000	14000 J	22000	- U	22000	- U	22000	- U	440		
Benzo(a)anthracene	µg/kg	- U	840	- U	2000	- U	2000	46000	22000	- U	22000	- U	22000	- U	440		
Benzo(b)fluoranthene	µg/kg	1200	840	1200 J	2000	- U	2000	68000	22000	- U	22000	- U	22000	- U	440		
Benzo(k)fluoranthene	µg/kg	- U	840	- U	2000	- U	2000	28000	22000	- U	22000	- U	22000	- U	440		
Benzo(g,h,i)perylene	µg/kg	490 J	840	970 J	2000	- U	2000	36000	22000	- U	22000	- U	22000	- U	440		
Benzo(a)pyrene	µg/kg	680 J	840	600 J	2000	- U	2000	45000	22000	- U	22000	- U	22000	- U	440		
Butyl benzyl phthalate	µg/kg	- U	840	1100 J	2000	- U	2000	16000 J	22000	- U	22000	- U	22000	- U	440		
Chrysene	µg/kg	820 J	840	740 J	2000	- U	2000	48000	22000	- U	22000	- U	22000	- U	440		
Dibenzofuran	µg/kg	90 J	840	- U	2000	- U	2000	3400 J	22000	- U	22000	- U	22000	- U	440		
Di-n-butyl phthalate	µg/kg	- U	840	430 J	2000	- U	2000	- U	22000	- U	22000	- U	22000	- U	440		
Di-n-octyl phthalate	µg/kg	760 J	840	- U	2000	- U	2000	- U	22000	- U	22000	- U	22000	- U	440		
bis(2-Ethylhexyl)phthalate	µg/kg	- U	840	3800	2000	- U	2000	2700 J	22000	- U	22000	- U	22000	- U	440		
Fluoranthene	µg/kg	2000	840	1600 J	2000	- U	2000	120000	22000	- U	22000	- U	22000	- U	440		
Fluorene	µg/kg	140 J	840	- U	2000	- U	2000	6700 J	22000	- U	22000	- U	22000	- U	440		
Indeno(1,2,3-cd)pyrene	µg/kg	540 J	840	670 J	2000	- U	2000	30000	22000	- U	22000	- U	22000	- U	440		
2-Methylnaphthalene	µg/kg	- U	840	- U	2000	- U	2000	- U	22000	- U	22000	- U	22000	- U	440		
Pentachlorophenol	µg/kg	120 J	4100	- U	9800	- U	9800	- U	11000	- U	11000	- U	11000	- U	2100		
Phenanthrene	µg/kg	1600 U	840	950 J	2000	- U	2000	85000	22000	- U	22000	- U	22000	- U	440		
Pyrene	µg/kg	1700 U	840	1200 J	2000	- U	2000	95000	22000	- U	22000	- U	22000	- U	440		
8080-PEST/PCB																	
Aroclor 1260	µg/kg	240	170	- U	81	- U	81	- U	890	- U	890	- U	890	- U	180		
4,4'-DDD	µg/kg	- U	17	- U	8.1	- U	8.1	150	89	- U	89	- U	89	- U	18		
4,4'-DDE	µg/kg	24	17	- U	8.1	- U	8.1	100	89	- U	89	- U	89	- U	18		
4,4'-DDT	µg/kg	56	17	- U	8.1	- U	8.1	- U	89	- U	89	- U	89	- U	18		
ORGANIC-OTHER																	
Total Petroleum Hydrocarbons	mg/kg	1010	255	3330	245	1680	271	60.3	26.8								

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

Source: WCC, 1993.

TABLE A.4 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN
SI SEDIMENT SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

		02/27/92 AR02 - Trend Report - B301 (SD) Hits Only 07:21:38									
		020697-0001-SA		019352-0002-SA		019408-0003-SA		019379-0002-SA			
Lab Sample Number:		B301-001-SD-000		B301-MH1-SD-001		B301-MH2-SD-001		B301-MH3-SD-001			
Collect Date:		30-Jan-92		26-Nov-91		03-Dec-91		02-Dec-91			
	Units	Value	RL	Value	RL	Value	RL	Value	RL	Value	RL
METAL											
Arsenic	mg/kg	7.7	1.3	2.4	.61	7.3	.5	1.6	.67		
Antimony	mg/kg	- U	7.7	26.5	7.4	4.4 J	8.1	- U	8		
Barium	mg/kg	234	1.3	215	1.2	827 J	1.4	373	1.3		
Beryllium	mg/kg	.21 J	.26	- U	.25	.35	.27	.19 J	.27		
Cadmium	mg/kg	2.7	.64	2.2	.61	6.9 J	.68	- U	.67		
Chromium	mg/kg	28.1	1.3	18.5	1.2	384	1.4	19.8	1.3		
Cobalt	mg/kg	8.2	1.3	- U	1.2	20.9	1.4	.82 J	1.3		
Copper	mg/kg	30	2.6	186	2.5	229	1.4	13.6	2.7		
Lead	mg/kg	277	63.9	469	30.6	2270	67.8	23.6	3.4		
Nickel	mg/kg	20.9	5.1	19.1	4.9	30.7	5.4	6.2	5.4		
Silver	mg/kg	21.9	1.3	1.4	1.2	- U	1.4	- U	1.3		
Tin	mg/kg	- U	12.8	3680	12.3	84.3	13.6	- U	13.4		
Vanadium	mg/kg	9.3	1.3	8.2	1.2	19.1	1.4	7.9	1.3		
Zinc	mg/kg	253	2.6	432	2.5	611	2.7	51.4	2.7		
Calcium	mg/kg	25800	25.5	24200	24.5	6530	27.1	42400	26.8		
Iron	mg/kg	9670	12.8	5960	12.3	44200	13.6	6000	13.4		
Magnesium	mg/kg	1880	25.5	1410	24.5	2590	27.1	1930	26.8		
Potassium	mg/kg	486 J	639	139 J	613	738	678	505 J	671		
Sodium	mg/kg	207 J	639	60.6 J	613	137 J	678	269 J	671		
Manganese	mg/kg	2200	1.3	85.1	1.2	275	1.4	171	1.3		
Mercury	mg/kg	.29	.13	- U	.12	1.2	.14	- U	.0002		
GEN-INORGANIC											
Cyanide	mg/kg	-	.64	- U	.61	4.5	.68	-			

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

TABLE A.4 (Cont.)
SUMMARY OF CHEMICALS DETECTED IN
SI SEDIMENT SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SD) Hits Only 07:21:38

Lab Sample Number: 019408-0002-SA
WCC Sample Number: B301-MH5-SD-001
Collect Date: 03-Dec-91

	Units	Value	RL
8240-VOLS			
Acetone	µg/kg	- U	20000
2-Butanone (MEK)	µg/kg	- U	20000
Methylene chloride	µg/kg	- U	10000
Toluene	µg/kg	- U	10000
Xylenes (total)	µg/kg	- U	10000
8270-SEMI-VOLS			
Acenaphthene	µg/kg	- U	68000
Anthracene	µg/kg	30000 J	68000
Benzo(a)anthracene	µg/kg	300000	68000
Benzo(b)fluoranthene	µg/kg	320000	68000
Benzo(k)fluoranthene	µg/kg	140000	68000
Benzo(g,h,i)perylene	µg/kg	110000	68000
Benzo(a)pyrene	µg/kg	170000	68000
Butyl benzyl phthalate	µg/kg	18000 J	68000
Chrysene	µg/kg	380000	68000
Dibenzofuran	µg/kg	- U	68000
Di-n-butyl phthalate	µg/kg	- U	68000
Di-n-octyl phthalate	µg/kg	- U	68000
Bis(2-Ethylhexyl)phthalate	µg/kg	77000	68000
Fluoranthene	µg/kg	740000	68000
Fluorene	µg/kg	7900 J	68000
Indeno(1,2,3-cd)pyrene	µg/kg	100000	68000
2-Methylnaphthalene	µg/kg	11000 J	68000
Pentachlorophenol	µg/kg	- U	33000
Phenanthrene	µg/kg	140000	68000
Pyrene	µg/kg	560000	68000
8080-PEST/PCB			
Aroclor 1260	µg/kg	- U	680
4,4'-DDD	µg/kg	51 J	68
4,4'-DDE	µg/kg	160	68
4,4'-DDT	µg/kg	- U	68
ORGANIC-OTHER			
Total Petroleum Hydrocarbons	mg/kg	21700	1020

B = Analyte detected in blank
J = Estimated value

Q = Value may not be site-related
R = Rejected value

RL = Reporting limit
U = Nondetected

Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

TABLE A.4

SUMMARY OF CHEMICALS DETECTED IN SI SEDIMENT SAMPLES

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

02/27/92 AR02 - Trend Report - B301 (SD) Hits Only 07:21:38

Lab Sample Number: 019408-0002-SA
WCC Sample Number: B301-MH5-SD-001
Collect Date: 03-Dec-91

	Units	Value	RL
METAL			
Arsenic	mg/kg	98.6	10
Antimony	mg/kg	- UJ	12.3
Barium	mg/kg	652 J	2
Beryllium	mg/kg	.41	.41
Cadmium	mg/kg	17.2 J	1
Chromium	mg/kg	193	2
Cobalt	mg/kg	11.7	2
Copper	mg/kg	678	4.1
Lead	mg/kg	4750	10.2
Nickel	mg/kg	46.7	8.2
Silver	mg/kg	2.8	2
Tin	mg/kg	1690	20.5
Vanadium	mg/kg	17.3	2
Zinc	mg/kg	3190	4.1
Calcium	mg/kg	5120	41
Iron	mg/kg	12700	20.5
Magnesium	mg/kg	2400	41
Potassium	mg/kg	1150	1020
Sodium	mg/kg	253 J	1020
Manganese	mg/kg	92.2	2
Mercury	mg/kg	- U	.2
GEN-INORGANIC			
Cyanide	mg/kg	1.7	1

B = Analyte detected in blank
J = Estimated value
Q = Value may not be site-related
R = Rejected value
RL = Reporting limit
U = Nondetected
Vols = Appendix IX volatile organics
Semi-Vols = Appendix IX semivolatile organics

TABLE A.5
SUMMARY OF RI GEOPROBE® WATER SAMPLE
ANALYTICAL RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Sample Location	Surface Elevation (msl)	Sample Depth (bgs)	Sample Elevation (msl)	TCE	Target VOCs (µg/L)		Comments / Problems
					C1,2DCE	1,1DCE	QA/QC
B301-GS1	1045	43	1002	1.7	2.1	ND	
	1045	55	990	16.7	ND	ND	
	1045	62	983	13.7	ND	ND	
B301-GS2	1056	54	1002	ND	ND	ND	
	1056	66	990	Trace	ND	ND	
B301-GS3	1044	45	999	ND	ND	ND	
B301-GS4	1059	60	999	1.3	4.3	ND	
B301-GS5	1059	51	1008	ND	ND	ND	
	1059	60	999	0.12	ND	ND	
B301-GS6	1050	44	1006	ND	ND	ND	
	1050	55	995	1.1	ND	ND	
	1050	62	988	75	2.6	ND	
B301-GS7	1057	51	1006	0.4	ND	ND	
	1057	67	990	6.7	14.6	ND	
B301-GS8	1055	50	1005	0.2	ND	ND	
B301-GS9	1052	63	989	0.3	ND	ND	Duplicate
B301-GS10	1055	50	1005	ND/ND	ND/ND	ND/ND	
B301-GS11	1054	48	1006	1.6	ND	ND	
B301-GS12	1047	55	992	ND	ND	ND	
	1047	65	982	ND	ND	ND	
B301-GS13	1043	50	993	ND	ND	ND	
B301-GS14	1059	54	1005	ND	ND	ND	
	1059	69	990	Trace	ND	ND	
B301-GS15	1060			NA	NA	NA	
B301-GS16	1059	65	994	145	0.9	ND	
B301-GS17	1035	50	985	6	ND	ND	
B301-GS18	1045	50	995	37/144	1.1/2.5	ND/ND	Duplicate
	1045	60	985	1300	7.7	6	
B301-GS19	1024	35	989	0.9	ND	ND	
	1024	45	979	187	0.4	ND	
B301-GS20	1024	55	969	3.5/3.5	ND/ND	ND/ND	Duplicate
B301-GS21	1035	50	985	Trace	ND	ND	
	1037	50	987	0.23	ND	ND	

Source: WCC, 1996.

TABLE A.5 (Cont.)
SUMMARY OF RI GEOPROBE® WATER SAMPLE
ANALYTICAL RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Sample Location	Surface Elevation (msl)	Sample Depth (bgs)	Sample Elevation (msl)	TCE	Target VOCs (µg/L)		Comments / Problems	
					C1,2DCE	1,1DCE	QA/QC	
B301-GS22	1044	50	994	2.8	ND	ND		Rubble
B301-GS23	1039	58	981	340	ND	ND		
B301-GS24	1029	50	979	27	ND	ND		
B301-GS25	1023	37	986	81.1	ND	ND		
	1023	45	978	433	ND	ND		
	1023	52	971	4.7	4.3	ND		
B301-GS26	1012	19	993	0.4	3.8	ND		
	1012	27	985	0.7	ND	ND		
	1012	35	977	ND	ND	ND		
	1012	45	967	ND	ND	ND		
B301-GS27	1035	57	978	14	ND	ND		
B301-GS28	1006	27	979	0.1	ND	ND		
	1006	37	969	20.3	ND	ND		
	1006	47	959	Trace	ND	ND		
B301-GS29	999	21	978	21.7/24.3	ND/ND	ND/ND		Duplicate
	999	31	968	0.9	ND	ND		
B301-GS30	993	15	978	66.5	ND	ND		
	993	20	973	1.6	ND	ND		
	993	30	963	12.2	ND	ND		
B301-GS31	993	5	988	0.4	ND	ND		Midwest: TCE= 4
	993	10	983	5.4	ND	ND		Midwest: TCE= 23 / CT= 6
	993	18	975	11.5	ND	ND		
	993	23	970	7.8	ND	ND		
	993	33	960	11.7	ND	ND		
	993	43	950	5	ND	ND		
	993	53	940	1.5	ND	ND		
B301-GS32	1011	16	995	Trace	ND	ND		
	1011	27	984	0.2	ND	ND		
	1011	32	979	0.1	ND	ND		
	1011	42	969	ND	ND	ND		
	1011	52	959	ND	ND	ND		
B301-GS33	1014	35	979	ND	ND	ND		
	1014	45	969	ND	ND	ND		

TABLE A.5 (Cont.)
SUMMARY OF RI GEOPROBE® WATER SAMPLE
ANALYTICAL RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Sample Location	Surface Elevation (msl)	Sample Depth (bgs)	Sample Elevation (msl)	Target VOCs (µg/L)			Comments / Problems QA/QC
				TCE	C1,2DCE	1,1DCE	
B301-GS34	993	9	984	ND	ND	ND	Duplicate
	993	33	960	ND/ND	ND/ND	ND/ND	
B301-GS35	993	43	950	ND	ND	ND	
	990	18	972	Trace	1.8	ND	
	990	23	967	Trace	1.7	ND	
	990	33	957	ND	ND	ND	
	990	43	947	6.6	1.1	ND	
B301-GS36	990	53	937	2.6	ND	ND	
	992	10	982	13.2	ND	ND	
	992	18	974	8.1	1.3	ND	
	992	28	964	0.4	ND	ND	
	991	8	983	5	3.2	ND	
B301-GS37	991	18	973	12.6	ND	ND	
	991	33	958	2.1	ND	ND	
	993	23	970	ND	ND	ND	
B301-GS38	993	43	950	ND	ND	ND	
	990	6	984	105	3.7	ND	
B301-GS39	990	15	975	57.8	16.9	ND	
	990	23	967	87.8	5.5	ND	
	990	33	957	Trace	0.4	ND	
	990	43	947	0.1	0.2	ND	
	989	9	980	2	ND	ND	
B301-GS40	989	20	969	2.4	ND	ND	
	989	30	959	Trace	ND	ND	
	1037	55	982	ND	ND	ND	
B301-GS41	1050	65	985	ND/ND	ND/ND	ND/ND	Duplicate
B301-GS42	1053	65	988	ND	ND	ND	
B301-GS43	989	12	977	2.2	ND	0.3	
B301-GS44	989	15	974	3.8	12	ND	
	989	23	966	1.1	9.9	ND	
	989	33	956	ND	2.5	ND	

TABLE A.5 (Cont.)
SUMMARY OF RI GEOPROBE® WATER SAMPLE
ANALYTICAL RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Sample Location	Surface Elevation (msl)	Sample Depth (bgs)	Sample Elevation (msl)	TCE	Target VOCs (µg/L)		Comments / Problems	
					C1,2DCE	1,1DCE	QA/QC	
B301-GS45	987	9	978	5.1/6.0	ND/ND	ND/ND	Duplicate	
	987	15	972	19.9/26.5	0.1/0.2	ND/ND	Duplicate	
	987	23	964	3.4	4.5	ND		
	987	33	954	2.3	ND	ND		
B301-GS46	1009	25	984	81.4	ND	ND		
	1009	33	976	103	ND	ND		
	1009	38	971	262	ND	ND		
	1009	48	961	4.8	ND	ND		
B301-GS47	1033	58	975	ND	ND	ND		
	1033	68	965	ND	ND	ND		
B301-GS48	1040	55	985	62.8	6.8	ND		
	1040	65	975	0.7	ND	ND		
B301-GS49	1055	65	990	340	8.2	ND		
B301-GS50	1056	66	990	4	ND	ND		
B301-GS51	1056	67	989	0.2	ND	ND		
B301-GS52	1056	67	989	ND/ND	ND/ND	ND/ND	Duplicate	
B301-GS53	1053	66	987	369	58	ND		
B301-GS54	1057	67	990	6.7	ND	ND	Midwest:TCE= 33	
B301-GS55	1057	69	988	182	ND	ND		
B301-GS56	1057	69	988	22	ND	ND		
B301-GS57	1058	69	989	>3000	129	ND		
	1058	74	984	1010	41	ND	Midwest:TCE= 22	
B301-GS58	1055	55	1000	3.9	ND	ND		
B301-GS59	1057	69	988	6.2	ND	ND		
B301-GS60	1056	69	987	20	10	ND		
B301-GS61	1058	69	989	405	ND	ND	Midwest:TCE= 2,750	
B301-GS62	1058	69	989	121/140	ND/ND	22.3/26	Duplicate	
B301-GS63	1055	66	989	939	ND	ND		
B301-GS64	1053	66	987	ND	ND	ND		
B301-GS65	993	15	978	ND	ND	ND		
B301-GS66	993	10	983	11.2	ND	ND		
B301-GS67	993	15	978	33.3	ND	ND		
B301-GS68	1065	76	989	ND/Trace	ND/ND	ND/ND	Duplicate	

Source: WCC, 1996.

TABLE A.5 (Cont.)
SUMMARY OF RI GEOPROBE® WATER SAMPLE
ANALYTICAL RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Sample Location	Surface Elevation (msl)	Sample Depth (bgs)	Sample Elevation (msl)	TCE	Target VOCs (µg/L)		Comments / Problems
					C1,2DCE	1,1DCE	QA/QC
B301-GS69	1044	60	984	0.3	ND	ND	
B301-GS70	980	15	965	0.7	ND	ND	
	980	26	954	0.1	ND	ND	
	980	40	940	ND	ND	ND	
	980	50	930	ND	ND	ND	
	980	57	923	ND	ND	ND	
B301-GS71	980	15	965	0.4	ND	ND	Midwest: ND
	980	26	954	ND	ND	ND	
	980	40	940	ND	ND	ND	
	980	50	930	ND	ND	ND	
	980	57	923	ND	ND	ND	
B301-GS72	979	15	964	29.1	ND	ND	
	979	26	953	2.1	ND	ND	
	979	40	939	ND/ND	ND/ND	ND/ND	Duplicate
B301-GS73	980	15	965	0.2	ND	ND	Midwest: TCE = ND
	980	26	954	Trace	ND	ND	
	980	40	940	ND	ND	ND	
	980	55	925	Trace	ND	0.3	
B301-GS74	982	15	967	135	45.4	ND	Midwest: TCE=220 / C1,2DCE=140 / VC=2
	982	26	956	Trace	3.8	ND	
	982	40	942	Trace	ND	ND	
	982	55	927	Trace	ND	ND	
B301-GS75	978	15	963	0.1	ND	ND	
	978	26	952	ND	ND	ND	
	978	40	938	ND/ND	ND/ND	ND/ND	Duplicate
B301-GS76	978	15	963	221	6.7	1.9	
	978	26	952	ND	ND	ND	
B301-GS77	977	15	962	6.6	ND	ND	Midwest: TCE = 45
	977	26	951	Trace	ND	ND	
B301-GS78	980	18	962	86.6	3.7	ND	
	980	29	951	Trace	2.2	ND	
B301-GS79	979	18	961	ND	6.3	ND	
	979	29	950	ND	1.9	ND	

TABLE A.5 (Cont.)
SUMMARY OF RI GEOPROBE® WATER SAMPLE
ANALYTICAL RESULTS

Building 301
 Intrinsic Remediation TS
 Offutt AFB, Nebraska

Sample Location	Surface Elevation (msl)	Sample Depth (bgs)	Sample Elevation (msl)	TCE	Target VOCs (µg/L)		Comments / Problems
					C1,2DCE	1,1DCE	QA/QC
B301-GS80	975	15	960	Trace	7.7	ND	Midwest: TCE= 5 / 11-TCA= 8 / 11DCA= 2
	975	26	949	Trace	ND	ND	
B301-GS81	975	15	960	0.9	ND	ND	
	975	26	949	Trace	ND	ND	
B301-GS82	975	15	960	Trace	13.3	ND	Midwest: C1,2DCE= 12 / T1,2DCE= 2
	975	26	949	0.2	15.1	ND	
	975	45	930	Trace	ND	ND	
	975	65	910	ND	ND	ND	
B301-GS83	973	15	958	Trace	2.9	ND	Midwest: C1,2DCE= 5
	973	26	947	ND	ND	ND	
	973	40	933	ND	ND	ND	
	977	15	962	12.4	3.2	ND	
B301-GS84	977	26	951	0.2	11.9	ND	Midwest: C1,2DCE= 12 / T1,2DCE= 2
	977	40	937	ND	ND	ND	
B301-GS85	977	15	962	8.5	ND	ND	
	977	26	951	0.1	ND	ND	
	977	40	937	0.1	ND	ND	Midwest: C1,2DCE= 5
B301-GS86	975	15	960	ND	ND	ND	
	975	25	950	Trace	ND	ND	
	975	40	935	ND	ND	ND	
B301-GS87	974	15	959	ND	ND	ND	Midwest: C1,2DCE= 12 / T1,2DCE= 2
	974	25	949	ND	ND	ND	
B301-GS88	974	15	959	ND	3.5	ND	
	974	25	949	ND	ND	ND	
B301-GS89	974	15	959	ND	ND	ND	Duplicate
	974	25	949	ND	ND	ND	
B301-GS90	975	15	960	ND	ND	ND	
	975	25	950	ND/ND	ND/ND	ND/ND	
B301-GS91	974	15	959	ND	ND	ND	Midwest: ND CT = Carbon Tetrachloride
	974	25	949	ND	ND	ND	
B301-GS92	973	15	958	0.3	ND	ND	
	973	25	948	Trace	ND	ND	

Trace = < 0.1

TABLE A.6
COMPARISON OF RI FIELD ANALYTICAL RESULTS WITH
LABORATORY ANALYTICAL RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Sample Location	Sample Depth (bgs)	Field Laboratory Results (µg/L) Headspace			Midwest Laboratory Results (µg/L) Method 8021A			
		TCE	C1,2DCE	1,1DCE	TCE	C1,2DCE	1,1DCE	OTHERS
B301-GS31	5	0.4	ND	ND	4	ND	ND	
	10	5.4	ND	ND	23	ND	ND	CT = 6
B301-GS54	67	6.7	ND	ND	33	ND	ND	
B301-GS58	55	3.9	ND	ND	22	ND	ND	
B301-GS61	69	405	ND	ND	2,750	ND	ND	
B301-GS70	57	ND	ND	ND	ND	ND	ND	
B301-GS73	15	0.2	ND	ND	ND	ND	ND	
B301-GS74	15	135	45.4	ND	220	140	ND	VC = 2
B301-GS77	15	6.6	ND	ND	45	ND	ND	
B301-GS81	15	0.9	ND	ND	5	ND	ND	111-TCA=8 11-DCA=2
B301-GS86	25	Trace	ND	ND	ND	5	ND	
B301-GS87	25	ND	ND	ND	ND	12	ND	T1,2DCE=2
B301-GS92	25	Trace	ND	ND	ND	ND	ND	

Trace = < 0.1

CT = Carbon Tetrachloride
111-TCA = 1,1,1-Trichloroethane
11-DCA = 1,1-Dichloroethane
T1,2-DCE = Trans 1,2-Dichloroethene
VC = Vinyl Chloride
Source: WCC, 1996.

TABLE A.7
SUMMARY OF RI HYDROPUNCH®
ANALYTICAL RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Date Sampled	Surface Elevation (msl)	Sample Depth (Feet bgs)	Sample Elevation (msl)	Sample Number	Concentration (µg/L)
8/2/95	1045	70	975	B301-HP-1-70	TCE = 2
8/3/95	1045	86	959	B301-HP-1-86	ND
8/4/95	1059	59	1000	B301-HP-2-59	TCE = 18
8/7/95	1059	75	984	B301-HP-2-75	TCE = 2
8/7/95	1059	90	969	B301-HP-2-90	ND
8/15/95	1045	72	973	B301-HP-3-72	TCE = 1
8/15/95	1045	72	973	B301-HP-53-72	TCE = 1
					Carbon Tet. = 4
8/25/95	1056	66	990	Attempt Failed	NA
8/29/95	1056	66	990	B301-HP-4-66	TCE = 725
8/29/95	1056	80	976	B301-HP-4-80	cis-1,2-DCE = 50 TCE = 2
8/30/95	1056	66	990	B301-HP-5-66	TCE = 25,500

TABLE A.8
SUMMARY OF RI MONITORING WELL
ANALYTICAL RESULTS

Building 301
Intrinsic Remediation TS
Offutt AFB, Nebraska

Location	Date Sampled	Screen Interval Elevation (MSL)	Sample Number	Concentration (µg/L)	QA/QC analyzed by Quanterra; (µg/L)
B301-MW1	4/11/96	1011.9-996.9	B301-001-MW-005	TCE=13 1,2-DCE=12 CT=11	
B301-MW2	4/15/96	1015.3-1000.3	B301-002-MW-005	ND	Carbon disulfide=130
B301-MW2D	4/15/96	962.6-957.6	B301-02D-MW-005	ND	Carbon disulfide=9.1
B301-MW6	4/15/96	1014.7-999.7	B301-006-MW-005	TCE=3.7	
B301-MW7S	4/10/96	1009.5-1005	B301-07S-MW-001	TCE=70 PCE=1.6	
B301-MW7I	4/15/96	990.1-985.6	B301-07I-MW-001	TCE=25,000 1,2-DCE=1500 Toluene=170	Estimated
B301-MW7D	4/10/96	965.6-961.1	B301-07D-MW-001	ND	
B301-MW8I	4/11/96	977.4-972.9	B301-08I-MW-001	TCE=280 1,1-DCE=6 CT=11	
B301-MW9S	4/15/96	984.9-975.4	B301-09S-MW-001	TCE=390 (Dup. 410) 1,2-DCE=29 (Dup. 30)	split (USACE-MRD LAB) Duplicate No. B301-26S-MW-001
B301-MW9I	4/11/96	953.9-949.4	B301-09I-MW-001	TCE=1.7 1,2-DCE=3.2	
B301-MW10S	4/11/96	971.5-962	B301-10S-MW-001	TCE=52	

Source: WCC, 1996.

TABLE A.9
SUMMARY OF RI SOIL ANALYTICAL RESULTS
BUILDING 301
INTRINSIC REMEDIATION TS
OFFUTT AFB, NEBRASKA

Analyte	Borehole ID	MW7I	MW7I	MW7I	MW7I	MW7I	MW10	MW11	MW12
	Sample Depth (ft/bgs)	25	35	45	60	58	9	11	13
Acetone ^{a/}		12	ND ^{b/}	ND	ND	ND	NA ^{c/}	NA	NA
Acetonitrile		ND	ND	ND	ND	ND	NA	NA	NA
Acrolein		ND	ND	ND	ND	ND	NA	NA	NA
Acrylonitrile		ND	ND	ND	ND	ND	NA	NA	NA
Allyl chloride		ND	ND	ND	ND	ND	NA	NA	NA
Benzene		3.7	4.8	1.8	4.2	2.4	NA	NA	NA
Bromodichloromethane		ND	ND	ND	ND	ND	NA	NA	NA
Bromoform		ND	ND	ND	ND	ND	NA	NA	NA
Bromomethane		ND	ND	ND	ND	ND	NA	NA	NA
2-Butanone (MEK)		ND	ND	ND	ND	ND	NA	NA	NA
Carbon disulfide		ND	ND	ND	ND	ND	NA	NA	NA
Carbon Tetrachloride		ND	ND	ND	ND	ND	NA	NA	NA
Chlorobenzene		ND	ND	ND	ND	ND	NA	NA	NA
Chloroethane		ND	ND	ND	ND	ND	NA	NA	NA
Chloroform		ND	ND	ND	ND	ND	NA	NA	NA
Chloromethane		ND	ND	ND	ND	ND	NA	NA	NA
Chloroprene		ND	ND	ND	ND	ND	NA	NA	NA
Dibromochloromethane		ND	ND	ND	ND	ND	NA	NA	NA
1,2-Dibromoethane (EDB)		ND	ND	ND	ND	ND	NA	NA	NA
Dibromomethane		ND	ND	ND	ND	ND	NA	NA	NA
trans-1,4-Dichloro-2-butene		ND	ND	ND	ND	ND	NA	NA	NA
Dichlorodifluoromethane		ND	ND	ND	ND	ND	NA	NA	NA
1,1-Dichloroethane		ND	ND	ND	ND	ND	NA	NA	NA
1,2-Dichloroethane		ND	ND	ND	ND	ND	NA	NA	NA
1,1-Dichloroethene		ND	ND	ND	ND	ND	NA	NA	NA
1,2-Dichloroethene		ND	ND	ND	ND	ND	NA	NA	NA
1,2-Dichloropropane		ND	ND	ND	ND	ND	NA	NA	NA
cis-1,3-Dichloropropene		ND	ND	ND	ND	ND	NA	NA	NA
trans-1,3-Dichloropropene		ND	ND	ND	ND	ND	NA	NA	NA
1,4-Dioxane		ND	ND	ND	ND	ND	NA	NA	NA
Ethylbenzene		ND	ND	ND	ND	ND	NA	NA	NA
Ethyl methacrylate		ND	ND	ND	ND	ND	NA	NA	NA
2-Hexanone		ND	ND	ND	ND	ND	NA	NA	NA
Iodomethane		ND	ND	ND	ND	ND	NA	NA	NA
Isobutanol		ND	ND	ND	ND	ND	NA	NA	NA
Methacrylonitrile		ND	ND	ND	ND	ND	NA	NA	NA
Methylene chloride		1.7	2.0	1.7	9.5	10	NA	NA	NA
Methyl methacrylate		ND	ND	ND	ND	ND	NA	NA	NA
4-Methyl-2-pentanone		ND	ND	ND	ND	ND	NA	NA	NA
Propionitrile		ND	ND	ND	ND	ND	NA	NA	NA
1,1,1,2-Tetrachloroethane		ND	ND	ND	ND	ND	NA	NA	NA
1,1,2,2-Tetrachloroethane		ND	ND	ND	ND	ND	NA	NA	NA
Tetrachloroethene		ND	ND	ND	ND	ND	NA	NA	NA
Toluene		7.9	6.7	2.9	9.1	6.9	NA	NA	NA
1,1,1-Trichloroethane		ND	ND	ND	ND	ND	NA	NA	NA

TABLE A.9 (Continued)
SUMMARY OF RI SOIL ANALYTICAL RESULTS
BUILDING 301
INTRINSIC REMEDIATION TS
OFFUTT AFB, NEBRASKA

Analyte	Borehole ID	MW7I	MW7I	MW7I	MW7I	MW7I	MW10	MW11	MW12
	Sample Depth (ft/bgs)	25	35	45	60	58	9	11	13
1,1,2-Trichloroethane		ND	ND	ND	ND	ND	NA	NA	NA
Trichloroethene		ND	ND	12	4.8	1.9	NA	NA	NA
Trichlorofluoromethane		ND	ND	ND	ND	ND	NA	NA	NA
1,2,3-Trichloropropane		ND	ND	ND	ND	ND	NA	NA	NA
Vinyl acetate		ND	ND	ND	ND	ND	NA	NA	NA
Vinyl chloride		ND	ND	ND	ND	ND	NA	NA	NA
Xylenes (total)		ND	ND	ND	ND	ND	NA	NA	NA
Total Organic Carbon ^{d/}		NA	NA	NA	NA	ND	0.74	0.34	0.76

^{a/} Volatile organics analyzed by USEPA Method 8240. Units expressed as µg/kg.

^{b/} ND = Not detected

^{c/} NA = Not analyzed

^{d/} TOC units expressed in percent. Analyzed by USEPA Method 9060.

APPENDIX B

ANALYTICAL METHODS, DATA USE, AND PACKAGING REQUIREMENTS FOR ENVIRONMENTAL SAMPLES

APPENDIX B

ANALYTICAL METHODS, DATA USE, AND PACKAGING REQUIREMENTS FOR SOIL AND GROUNDWATER SAMPLES

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil/ Sediment	Aromatic and chlorinated hydrocarbons (BTEx, PCE, TCE, DCE, VC)	Purge and trap GC method SW8240 or RSKSOP-124	Handbook method modified for field extraction of soil using methanol	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each soil sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples or RSKSOP-102 and RSKSOP-120	Procedure must be accurate over the range of 0.01–15 percent TOC	The rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the aquifer matrix.	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis).	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Water	Aromatic and chlorinated hydrocarbons (BTEx, trimethylbenzene isomers, PCE, TCE, DCE, VC, chloromethane, chloroform, other relevant compounds)	Methods SW8010/8020 or SW8240 or RSKSOP-148	Handbook methods; analysis may be extended to higher molecular weight alkylbenzenes	Method of analysis for BTEx & CAHs, which are the primary target analytes for monitoring natural attenuation; BTEx & CAH concentrations must also be measured for regulatory compliance; trimethylbenzenes are used to monitor BTEx plume dilution if degradation is primarily anaerobic. Chloromethane and chloroform are indicators of CAH contamination by aerobic pathways.	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base

APPENDIX B (continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Preservation	Field or Fixed-Base Laboratory
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure.	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Each sampling round	Measure dissolved oxygen on site using a flow-through cell	Field
Water	Nitrate	IC method E300 or Hach Method #8039	Method E300 is a Handbook method.	Substrate for microbial respiration if oxygen is depleted.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container, add H ₂ SO ₄ to pH 2, cool to 4°C	Fixed-base
Water	Iron (II) (Fe ²⁺)	Colorimetric Hach Method # 8146	Filter if turbid.	May indicate an anaerobic degradation process due to depletion of oxygen, and nitrate.	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Sulfate (SO ₄ ²⁻)	IC method E300 or Waters Capillary Electrophoresis Method N-601	Method E300 is a Handbook method, if this method is used for sulfate analysis, do not use the field method.	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container, cool to 4°C	Fixed-base
Water	Sulfate (SO ₄ ²⁻)	Hach method # 8051	Colorimetric, if this method is used for sulfate analysis, do not use the fixed-base laboratory method.	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container, cool to 4°C	Field
Water	Methane, ethane, and ethene	Kampbell <i>et al.</i> , 1989 (RSKSOP-147) or SW3810 Modified	Method published by researchers at the US Environmental Protection Agency.	The presence of CH ₄ suggests BTEX or other carbon degradation via methanogenesis. Ethane and ethene data are used where chlorinated solvents are suspected of undergoing anaerobic biological transformation.	Each sampling round	Collect water samples in 50 mL glass serum bottles with butyl gray/Teflon-lined caps; add H ₂ SO ₄ to pH 2, cool to 4°C	Fixed-base

APPENDIX B (continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Carbon dioxide	Hach test kit model CA-23; Chemetrics Method R-1910; Hach Method 1436-01	Titrimetric; alternate method	The presence of free CO ₂ dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the CO ₂ concentrations should be compared with background levels to determine if they are elevated; elevated concentrations of CO ₂ could indicate biodegradation of dissolved contaminants.	Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Alkalinity	Hach Alkalinity test kit model AL AP MG-L, Method 8221	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater.	Each sampling round	Collect 100 mL of water in glass container	Field
Water	Oxidation-reduction potential (ORP)	A2580B	Measurements made with electrodes; results are displayed on a meter, protect samples from exposure to oxygen. Report results against a silver/silver chloride reference electrode	The ORP of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the ORP of groundwater may range from more than 800 mV to less than -400 mV.	Each sampling round	Collect 100-250 mL of water in a glass container, filling container from bottom; analyze immediately	Field

APPENDIX B (continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	pH	Field probe with direct reading meter.	Field	Aerobic and anaerobic processes are pH-sensitive.	Each sampling round	Collect 100-250 mL of water in a glass or plastic container, analyze immediately	Field
Water	Temperature	Field probe with direct reading meter.	Field only	Well development.	Each sampling round	Not Applicable	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Each sampling round	Collect 100-250 mL of water in a glass or plastic container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl ⁻ C or Waters Capillary Electrophoresis Method N-601	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system, elevated concentrations may also indicate biodegradation of CAHs.	Each sampling round	Collect 250 mL of water in a glass container	Fixed-base
Water	Chloride (optional, see data use)	Hach Chloride test kit model 8-P	Silver nitrate titration	As above, and to guide selection of additional data points in real time while in the field.	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Dissolved Organic Carbon		Laboratory	Used to classify plume and to determine if CAH biodegradation is possible in the absence of anthropogenic carbon.	Each sampling round	Collect 100 mL of water in a glass container, cool	Laboratory

APPENDIX B (concluded)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
ADDITIONAL (OPTIONAL) ANALYSES							
Water	Biochemical Oxygen Demand	EPA Method 405.1			Each sampling round	Collect 2 L of water in a glass container, cool to be determined	Laboratory
Water	Hydrogen (H ₂)		Relatively new analysis; data useful for evaluating biodegradation processes operating at a given time	Indicator of terminal electron-accepting processes operating at a site.	Each sampling round		
Water	Oxygenates (including methanol and acetone)	Optional; SW 8015 Modified			Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Laboratory
Water	Alcohols, ethers, and acetic acids	Optional; SW 8015 Modified		Optional carbon sources for biodegradation.	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Laboratory
Water	Acetaldehydes	Optional; GC/MS method to be determined			Each sampling round	to be determined	Laboratory
Water	Aliphatic Fatty Acids	Optional; GC/MS method to be determined		Byproducts of biodegradation processes; indicators of biodegradation and cometabolism.	Each sampling round	to be determined	Laboratory
Water	Organic Acids	Optional; GC/MS method to be determined		Optional carbon sources and byproducts of biodegradation processes.	Each sampling round	to be determined	Laboratory

NOTES:

- * Analyses other than those listed in this table may be required for regulatory compliance.
- 1. "Hach" refers to the Hach Company catalog, 1990.
- 2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
- 3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, USEPA, 1983.
- 4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
- 5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
- 6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, USEPA, 3rd edition, 1986.
- 7. "ASTM" refers to the *American Society for Testing and Materials*.
- 8. "LUFT" refers to the State of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
- 9. "RSKSOP" refers to a standard operating procedures developed by the USEPA NRMRL (formerly the Robert S. Kerr Environmental Research Laboratory).